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# Agro-Terrorism:
# What Is the Threat?

## Proceedings of a Workshop Held at Cornell University, Ithaca, N.Y. November 12-13, 2000

Co-Editors
Jason Pate and Gavin Cameron

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# Contents

# Preface: WMD Terrorism: As Terrorism Evolves, Is Agriculture a Likely Target?

*John Parachini*

In the late 1980s, a new phase in the history of terrorism emerged characterized in part by mass and indiscriminate violence.[1] Then in 1995 came the attack with liquid sarin on the Tokyo subway. Since then, the United States has anticipated and planned to respond to terrorist use of nuclear, biological, or chemical weapons. Many observers believed that the Aum Shinryko's use of a chemical as an indiscriminate and mass casualty weapon marked the advent of a new phase in terrorism.[2] Despite the fears of terrorist attacks with so-called weapons of mass destruction (WMD), such attacks have not been a significant feature of this new wave of terrorism.

The first serious terrorist attack to occur with unconventional weapons material since the Tokyo incident was the anthrax attacks in the US in 2001. The attack caused five tragic deaths and revealed that authorities were not prepared to manage the consequences of a comparatively limited bioterrorist attack. After months of investigation involving 4000 FBI agents, authorities have yet to apprehend a suspect. Oddly, a consensus is forming that the perpetrator of these anthrax attacks is a former or current employee or employees in the US biological defense program, not a foreign terrorist group or domestic militia group.[3] Although Al-Qaeda showed considerable interest in obtaining WMD capabilities, there are no reports thus far indicating that it has done so. Thus, the state of the WMD terrorist threat is framed by a highly motivated terrorist group that has killed thousands, but has failed to assemble significant capabilities and a highly skilled individual or individuals with capabilities, but seemingly motivated to sow panic rather than to inflict mass casualties.

The residual impact of the anthrax attacks and Al-Qaeda's interest in WMD remains a daunting challenge. The threat of future biological weapons attacks has increased as a result of the anthrax attacks and how they were handled. Panicked approaches to countering bioterrorism have unfortunately drawn attention to the potential of biological weapons. Al-Qaeda leader Ayman Al-Zawahri noted in a memo recovered from a computer disk in Afghanistan that "we only became aware of [biological weapons] when the enemy drew our attention to them by repeatedly expressing concern that they can be produced simply."[4] A picture of former Defense Secretary William Cohen holding a bag of sugar as an example of the small amount of anthrax needed to kill thousands was found in one of the Al-Qaeda safehouses in Afghanistan. This is an example of how carefully terrorists monitor U.S. counterterrorism and incident-response activities. In summary, heightened expressions of concern and preparations to respond to terrorist attacks with biological weapons may seed ideas in peoples' minds with unintended consequences.

## Is Agro-Terrorism Next?

Concern that terrorists might attack US agricultural targets or food sources has grown since 1995 and assumed new proportions since September 11$^{th}$ and the anthrax attacks of Fall 2001. Many observers note the vulnerability of agricultural production and food processing to intentional attack, the importance of agriculture to the American economy, and the comparative ease with which biological agents might be employed against livestock and crops.[5] Warnings that "a biological attack that targets agriculture, therefore, should be regarded as a 'high-consequence, high-probability' event and receive the attention it deserves as a grave national security risk" are typical in scholarly journals on the topic.[6]

Revelations about the anti-agricultural biological weapons programs in the former Soviet Union and Iraq have also contributed to a heightened sense of concern about potential agro-terrorist attacks.[7] State anti-agriculture programs, particularly those of the former Soviet Union or other countries with nascent biological weapons programs, present three problems. First, state programs can assemble the capabilities to pose a serious threat under any circumstance. Second, with the breakup of the Soviet Union, many experts fear that economically stressed former weapons scientists may sell biological weapons material or their expertise to terrorist groups. Third, states that provide support to terrorist groups that are also developing biological weapons may provide weapons material or expertise to their client groups. Because anti-agricultural agents may be easier to handle than anti-human agents, state sponsors of terrorists might be more willing to pass these capabilities to terrorists.

Recent natural outbreaks of animal disease, such as foot and mouth disease (FMD) in the United Kingdom, contribute to the heightened concern. These natural outbreaks revealed the difficulties authorities have in responding effectively. Consolidation in farming and food processing also has created vulnerability to contagious diseases that might not have been such an acute danger to the economy when agriculture production was more dispersed. Finally, tremendous advances in biotechnology undertaken for positive purposes can also be exploited for evil. All of these factors combine to underscore the danger of terrorist attacks with WMD, principally biological agents, against agriculture.

## Historical Record

Despite all of the factors pointing to an increased possibility of biological terrorism against agriculture, there are surprisingly few historical examples of intentional attacks by subnational actors or states against agricultural production and food processing. What explains the paucity of attacks? Is the historical experience about to change dramatically?

In the 20th century, there are a few examples of states using biological agents clandestinely. In the First World War, Germany sought to disrupt allied logistical capabilities by infecting horses with glanders.[8] During the Second World War, Japan experimented with a number of different biological agents against crops in China.[9] In 1970, a UN resolution and press reports alleged that Portuguese government forces used a crop-eradication chemical agent on sweet potato crops in Angola territory controlled by the Popular Movement for the Liberation of Angola.[10] Former Soviet bioweaponeer Ken

Alibek alleged that the Soviets used glanders against the Afghan rebels' pack animals.[11] Finally, some commentators alleged that the Rhodesian government intentionally spurred an outbreak of anthrax in the cattle stock of Black Rhodesians.[12] Thus, over the course of the 20th century, there were only a handful of state-perpetrated attacks against agriculture and the impact was fairly limited.

The history of subnational entities attacking agricultural targets is similarly rare and ineffective. Two of the cases most frequently cited in the literature of so-called agricultural terrorism, the poisoning of Israeli citrus and Chilean grapes, resulted in considerable economic losses. Recent research suggests that the literature describing these incidents is substantially incorrect.[13] In the Israeli citrus case, contamination that occurred in Europe was attributed to an individual who claimed affiliation with the Palestinian cause, but whose actual connection to Palestinian elements is doubtful. In the Chilean grapes case, while an individual or individuals threatened to poison grapes, the fruit may not actually have been poisoned. In both of these incidents, contamination of some of the product inadvertently occurred in laboratories testing for the presence of poison.

In the few cases when subnational actors have attacked agriculture, the perpetrators have frequently been motivated by visceral hatred or private benefit rather than a political plan to inflict mass economic damage. For example, in the 1970s, members of the Ku Klux Klan poisoned the cattle of a nearby African-American Muslim farm in an attempt to force the community out of the area.[14] Approximately 30 cattle died from poisoning with cyanide. In another case in the 1990s, the owner of an animal feed company sought to hurt the business of his competition by clandestinely contaminating his competitor's product.[15] The contamination was discovered before any animals were sickened, and the perpetrator was apprehended. The historical record suggests that individuals or fringe groups isolated from the mainstream of society may resort to attacks on plants and animals, but this has been rare and the damage quite limited.

## Agro-Terrorist Motivations

Understanding why agro-terrorism is so infrequent despite the vulnerabilities is important in devising effective strategies for limiting the threat. Further analysis of why terrorists do not attack what seems to be a vulnerable high-value target is warranted. Augmenting the factors that inhibit such attacks may complement measures that are preventive and protective.

Terrorists who are committed to inflicting serious death and destruction do not resort to attacks on plants and animals. Serious terrorists who might be capable of causing significant damage to agriculture do not get the same psychological gratification from killing animals or destroying crops that they do from killing people or destroying buildings or crashing airliners. Those who do exploit the vulnerabilities of agricultural production and food processing have historically not been capable or willing to inflict the scale of damage that we fear.

The delayed effect of most biological weapons may explain in part why they have been used so infrequently. Terrorists feel greater power and affirmation with weapons that have an immediate effect. They are drawn to explosives for psychological reasons that are similar to those of arsonists who are drawn to fire. Terrorists often seek to affirm their superiority by wielding power over others. They crave the sense of power that explosives can provide. The mastermind of the 1993 World Trade Center bombing, Ramzi Yousef, described himself as a "genius" and an "explosive expert" who sought to topple one tower into the other to kill 250,000 people. Oklahoma City bomber Timothy McVeigh talked about his bombing of the Alfred P. Murrah federal building as "a shot to be heard around the world." These grandiose visions could never be matched by the aspiration of killing all of the hogs in the country or damaging the nation's wheat crop, even if these eventualities might have profound economic consequences. Neither would be a strategic blow to the country. Animals and crops are cultivated for economic benefit, and these capabilities can be reconstituted. In contrast, human lives are not replaceable.

## State Reluctance To Wage Agro-Terrorism

A number of factors help explain why states are reluctant to resort to attacks on agriculture. First, the effectiveness of an anti-agricultural attack is comparatively difficult to anticipate. It is hard to predict the evolution of a small attack with a contagious disease. Second, in order to conduct a truly devastating attack with high confidence of significant impact on the economic and political stability of a country, particularly a country as large as the United States, the size of the attack would have to be such that its discovery is more likely. Third, if a state clandestinely attacked agricultural assets of an adversary and the origin of the attack was eventually discovered, the offending state would risk devastating retaliation. The use of any biological agent could be construed as an attempted strategic strike. Finally, while the disincentives for state attacks on plants and animals will not necessarily constrain a subnational actor, state sponsors of subnational actors will be motivated to restrain their client groups for fear that their assistance may be discovered.

The benefits of agricultural production and trade foster a taboo against state-conducted or state-sponsored attacks on agriculture. States struggle to feed their own populations. The benefits of agricultural production and trade are powerful incentives to guard against natural disease outbreaks. In general, states would only take the risk of using WMD when they felt they could strike a strategic blow against an adversary or if their survival as a state was at stake. In these circumstances, states are much more likely to use WMD to kill adversary populations or invading armies rather than plants and animals. The risks and the limited military benefits of attacking agricultural assets make such attacks unlikely.

## Scope and Magnitude of the Agro-Terrorism Threat

Protecting food and agriculture is a dual-use problem with dual-use solutions. Naturally occurring outbreaks of disease that damage crops, kill livestock, and contaminate food products are as unpredictable and challenging as attacks perpetrated by people. Increased disease surveillance, preventive measures, and planned responses are as valuable for natural outbreaks as they are for intentional attacks. While many trends seemingly make cultivation and processing more vulnerable, given consolidation, these same trends make it easier to perform effective surveillance and to take cost-effective protective measures.

While state and terrorist attacks against food and agriculture have historically been quite rare, the probability for the future is hard to calibrate. Despite the paucity of historical cases, the probability is not zero. Augmented disease surveillance and cost-effective protective measures will reduce, but not eliminate, the probability of either natural or intentional outbreaks. However, it is noteworthy that neither the Director of Central Intelligence nor a recently released Defense Science Board study mentions the threat of attacks on agriculture as being anything close to a grave risk to national security.[16] Thus, while there is some danger to agricultural assets from WMD terrorism, in the post-September 11$^{th}$ period, it pales in comparison to other threats the United States faces.

John Parachini is a Policy Analyst with the RAND Corporation. The views expressed here are the author's own and do not represent the views and opinions of RAND or its research sponsors.

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# Introduction

The United States has been long concerned about acts of terrorism involving weapons of mass destruction (WMD), including the use of chemical or biological agents. Over the past few years, increasing attention in the United States and Europe has focused on the threat of bioterrorism, primarily against human populations, both military and civilian. More recently, however, this concern has extended to attacks on agriculture. The reasons for this trend are varied, but they include a growing awareness of the vulnerability of US agriculture to attack, and the highly publicized outbreaks of disease such as West Nile Fever in the United States and the devastating epidemics of bovine spongiform encephalopathy (BSE) ("mad cow disease") and foot-and-mouth disease (FMD) in Europe. These factors, particularly when combined with the widespread impression that the terrorist threat to the United States is increasing, have led some analysts to conclude that agricultural bioterrorism is an emerging security threat to the nation.

Agricultural bioterrorism is defined as the malicious use of plant or animal pathogens to cause devastating disease in the agricultural sector. Currently, this topic has received increased attention and discussion within academic, media, and government circles. The US agriculture sector, with subsidiary dependent industries, accounts for around one-sixth of the nation's gross domestic product and one-eighth of its employment. Some analysts contend that the agricultural sector is highly vulnerable to an attack. The potential consequences of a malicious attack on agriculture can be seen in naturally occurring disease outbreaks elsewhere in the world, which have cost billions of dollars and temporarily wrecked entire industries. The costs of a major disease outbreak may affect not only the farmer or producer, but also a series of associated groups and individuals, from agricultural workers and processing facilities to shippers, retailers, and finally consumers.

Recent independent and government-sponsored reports on the subject of agricultural bioterrorism have concluded that US agriculture is at risk, but that the danger remains poorly understood and, as yet, little discussed and evaluated.[1] Press reports and the few studies in the academic literature have tended to focus on the vulnerabilities of US agriculture, invoking worst-case scenarios. Most of these studies argue that agricultural bioterrorism is a new and dire threat to US national security and the agricultural sector. Is this correct? What evidence is available to support or challenge such assessments? A thorough understanding of the risk of agricultural bioterrorism involves not only assessing the inherent vulnerabilities of US agriculture, but also understanding terrorist capabilities and motivations.

To better analyze this threat from a diversity of perspectives, the Peace Studies Program at Cornell University hosted a workshop entitled, "Agro-Terrorism: What Is the Threat?" that was held on November 12-13, 2000, in Ithaca, New York. The workshop was a joint project of the Center for Global Security Research at Lawrence Livermore National Laboratory, the Center for Nonproliferation Studies at the Monterey Institute of International Studies, and the Peace Studies Program at Cornell University. The workshop sought out and explored perspectives across the spectrum on the issue of agricultural bioterrorism. In doing so, the workshop brought together a relevant cross-section of scientists, policymakers, and international security scholars to examine this potential threat (see list of participants in Appendix B). In a departure from previous studies, this workshop provided a forum to investigate the historical record, empirical evidence of terrorist intentions, and the technical hurdles to carrying out an effective agricultural bioterrorist attack.

The proceedings include edited and revised versions of the key papers presented at the workshop. This volume is arranged into three sections: *Historical Case Studies*, *Technical Issues*, and *Policy Responses*. As a preface, the proceedings begin with a provocative paper by John Parachini of the Monterey Institute, "WMD Terrorism: As Terrorism Evolves, Is Agriculture a Likely Target?" This paper frames the issue of agricultural bioterrorism with an analysis of what we know regarding terrorist objectives and motivations. An understanding of terrorist groups' motivations is an important element of meaningful threat assessment. What is it that feeds the bioterrorist psyche? Which terrorists are willing to inflict human casualties? Those who wish to do so may not be interested in agricultural bioterrorism. The converse is also true: if terrorists are reluctant for whatever reason to kill people, then agricultural bioterrorism may be more appealing. Along this same line of questioning, it is worth considering how agricultural bioterrorism relates more broadly to terrorism with biological weapons (BW) directed against human targets. Does agriculture offer simply an alternative target, possibly one with fewer counterproductive side effects? Is agricultural bioterrorism qualitatively different from other types of terrorism? Or are most terrorists simply not interested in biological weapons?

The first section of the proceedings presents three historical case studies of the use of anti-agriculture weapons by state and non-state actors. Simon Whitby and Piers Millet, from the University of Bradford, examine former (and suspect) state-level anti-agriculture BW programs. Their paper illustrates that nearly all state programs have included dedicated efforts to develop anti-agricultural biological weapons. These efforts have involved significant infrastructure, resources, and personnel for research, development, and weaponization. Whitby and Millet argue that for states, attacking livestock production, food, and cash crops with disease is potentially less technically demanding than launching BW attacks against personnel. This suggests that anti-agricultural BW may continue to be a threat from states hostile to the United States. The uncovering of Iraq's anti-crop BW program lends support to this hypothesis.

Peter Chalk of the RAND Corporation explores the historical record for use of agricultural pathogens by nonstate actors and identifies a number of relevant factors. For substate actors and groups, Chalk argues that agricultural bioterrorism is a new and underappreciated threat. He points out that terrorists have been shown to engage in infrastructure attacks that do not involve a loss of human life. The series of threats by Palestinian groups to contaminate Israeli fruit, and thus undermine exports, is an excellent example of this infrastructure approach. Chalk hypothesizes that the fact that more serious attacks have not occurred may be because terrorists have not thought about it or may consider this form of aggression unsuited to their objectives. However, Chalk also finds that the increase in the number of access points from the farm to the kitchen table, as well as the lack of security practices and surveillance in the agricultural industry to malicious acts, raise the future risk of an agricultural bioterrorism event. Because of this, Chalk proposes that attacks on food products, rather than field animals or crops, constitute the most serious threat in the near term.

To expand on the Whitby and Millet and the Chalk papers, Milton Leitenberg of the University of Maryland explores the historical linkages between state and substate anti-agriculture programs. His paper provides interesting counterarguments to the preceding papers and to the concept of state/substate BW linkages. Leitenberg finds that there is no historical evidence of transfer, or "leakage," of technology or personnel from state BW programs to nonstate actors. He does, however, report evidence for the transfer of BW technology and expertise among state programs, with Russia and Iran being notable examples. Leitenberg's findings are consistent with Whitby and Millet's concern about parallel technology transfer among state BW programs. For substate actors, Leitenberg emphasizes that it is no trivial task to acquire a BW capability, as evidenced by the size and complexity of state BW programs. These points suggest that terrorists would be at a disadvantage in launching an effective BW attack—even against crops and livestock. As a further counterargument, Leitenberg asserts that the historical record primarily shows a large number of fraudulent allegations of BW use, hoaxes, and threat-mongering by the media and the Clinton administration. From this, Leitenberg concludes that agricultural bioterrorism is more hype than reality, and that natural disease outbreaks, mammalian and insect pests, and poor storage conditions account for far greater losses of international crops and livestock.

The historical record suggests that at the low end (low-tech), malicious disease attacks on crops and livestock appear to be easy and capable of causing an effect. However, it remains unclear whether these low-level attacks are the product of intent or of technical limitations. There is little indication that terrorists have sought to carry out more extensive attacks, but it is still unclear why this is so and whether this will change in the future. Questions continue to abound: What is the sophistication level necessary to achieve a major act of agricultural bioterrorism, and do substate groups have that capability? If not, will they acquire new expertise or find experts to fill the gap? To search for answers to some of these questions, we now turn to an analysis of the technical constraints.

Concerning technical issues, it is useful to analyze the various factors involved in turning animal and plant pathogens into potential biological weapons. These factors are the same ones used to determine the technical feasibility of BW against humans and involve: (1) acquisition of a suitable pathogen, (2) growth of the pathogen, (3) processing the pathogen for delivery, (4) constructing an appropriate delivery device, and (5) releasing the agent under optimal environmental and meteorological conditions. It is important to evaluate each of these factors to determine where particular barriers for the likely state or substate actor(s) may arise.

Two papers in the proceedings are by plant and animal disease specialists from Cornell University. William Fry, plant pathologist, explores the hurdles involved in launching anti-crop terrorism. He suggests that environmental factors are paramount in the success of any plant disease outbreak. Without the proper environmental conditions (i.e., temperature, moisture), no plant disease outbreak will occur. Such environmental factors are extremely difficult for terrorists (or even states) to manipulate or overcome, even with access to sophisticated technical expertise. Furthermore, effective response strategies are available that can mitigate the destructive effects of plant disease outbreaks. For this reason, Fry argues that widespread plant disease outbreaks by terrorist groups are unlikely. However, Fry does not rule out the possibility that localized sabotage attacks against crops could be within the technical capabilities of certain terrorists.

In spite of these vulnerabilities, certain technical constraints would face a terrorist seeking to use animal pathogens to destroy US livestock. For example, for each animal pathogen, a successful widespread disease outbreak requires the synergy of several different factors, such as use of a virulent pathogen, proper infectious dose, environmental hardiness, and ease of transmission. Only a small number of agents possess all of the characteristics needed to facilitate a successful, widespread disease outbreak. Furthermore, large-scale attacks would likely require use of large quantities of agent and more sophisticated delivery systems, increasing the requirements for technical expertise. Several scenarios presented at the workshop could circumvent these technical requirements. It is not clear, however, whether terrorists would think of these actions or effectively carry out these scenarios.

Finally, in assessing the impact of an agricultural bioterrorism event, it is useful to assess both the short-term and long-term financial impacts. Jason Pate and Gavin Cameron, the co-editors of these proceedings, assess the costs that might result if a small-scale or large-scale terrorist attack were launched against US agriculture. Destruction of crops or livestock would have a direct financial impact on the grower or breeder. Depending on the scale of the attack, it is also possible that the attack will affect consumers, both in their confidence in the food supply (i.e., distrust of "tainted" or "contaminated" food) and in their pocketbooks. Pate and Cameron, however, remain skeptical of complete national economic devastation resulting from an agricultural bioterrorist attack.

In terms of response, Dorothy Preslar, of the Federation of American Scientists, examines the state of national and global animal and plant disease surveillance and assesses whether these systems are adequate to deal with either natural or malicious disease outbreaks. She emphasizes the disconnects between monitoring and surveillance from the local farm to the national levels and between nations. Augmenting surveillance and diagnostic capabilities would help to prevent and contain outbreaks and ensure a safe and ample food supply, providing benefits to society beyond the bioterrorist threat scenario. Rapid detection and identification of a pathogen would be an essential first step in minimizing the impact of a disease outbreak, deliberately induced or not. Finally, the proceedings conclude with conclusions about the main points raised during the workshop discussions. A workshop schedule, a list of participants, and information on the contributors are included in the appendices.

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# Panel I:
# Historical Case Studies

# State Agro-BW Programs

*Piers D. Millett and Simon M. Whitby**

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State investigations into anti-agricultural warfare can be divided into two distinct but related groups. Such groups are defined in relation to specific targets: animals and crops. During World War II and in the post-war period, a number of states conducted investigations into both offensive and defensive developments in anti-agricultural Biological Weapons (BW). More recently, it has come to light that other states have expressed an interest in obtaining BW weapons that might be directed against animals and crops. This paper focuses only on the offensive aspects of such programs, as defensive programs are legal under international law and the sheer numbers of them make it beyond the scope of this paper to deal with all of them. The state-run anti-agricultural programs concerned with the development of anti-animal capabilities are addressed first, then programs concerned with the development of anti-crop capabilities. In the pages that follow, we draw on both secondary source material and previously classified literature (from the US and the UK).[1] We argue that attacking livestock production and the production of food and cash crops is potentially less technically demanding than for offensive BW operations directed against personnel. While reductions in livestock and crop production may not directly result in significant reductions in calorific intake, as was initially investigated by the US and the UK,[1] in the populations of advanced industrialized countries, the economic consequences of an attack against livestock and/or crops could be potentially devastating.

## State Anti-Animal BW Programs

To present an overview of state-run anti-animal BW programs, this section begins by examining the nature of the most common organisms used in these programs and the weapons in which they are used. Particular

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attention is paid to the zoonotic nature of these diseases and the problems this presents in classifying state-run anti-animal BW programs. Zoonotic diseases have formed the backbone of many historical BW programs and constitute a major part of the information published to date. An overview of the programs, run by those states for which documentation exists, is presented. Although no primary documentation for the Russian (and Soviet) program is available in the public domain, this program is included under this classification as it is often taken to be proven in contemporary literature. A list of other possible possessor countries is also included in this section. The case study of the German World War I program illustrates the nature of a state-run anti-animal BW program. The consequences of such an attack are illustrated using information taken from a recently declassified 1954 study by the British Ministry of Defence into the susceptibility of UK agriculture to attack with foot-and-mouth disease (FMD). The implications of this study are strikingly similar to the 2001 outbreak of the disease in the UK. The implications of such an attack are brought up to date by examining the state of livestock-based agriculture in the USA at present and in the short-term future.

Establishing the existence of state-run anti-animal BW programs is intrinsically complicated and demonstrates all of the difficulties attributed to anti-plant and anti-personnel programs, as well as a subset of its own problems. Most micro-organisms used in anti-animal programs are zoonotic—although their natural host is an animal, they are also pathogenic to man. This attribute makes them strong candidates as anti-personnel weapons. The duality of these organisms, being used in both anti-personnel and anti-animal programs, makes differentiating between the two difficult. A prime example of this complication is the use of *Bacillus anthracis*. During World War II, anthrax was the chosen disease of "Operation Vegetarian," a British-led project designed to create an Allied anti-animal retaliatory capability. It is also internationally recognized as the most easily attainable anti-personnel biological weapon.

The strongest criterion for establishing the existence of an offensive anti-animal BW program rather than a defensive program is some form of documentation for intended use of biological weapons, as in the case of "Operation Vegetarian." As documentary evidence proving intentions is very rare, it is necessary to pursue another angle of enquiry. The next obvious criterion, as with anti-plant agents, is to examine the microorganisms involved, a process that is not without its own problems. Some programs, however, did perform research on organisms that were not zoonotic, and would be of little value as anti-personnel agents.

Of the list of agents that have been established to have been used in anti-animal programs (Table 1), those generally agreed to have a dual human and animal use capability are all bacteria, while those with a strictly anti-animal capability are mainly viruses. The high-risk organisms used in the anti-animal programs, such as FMD, swine fever, and Newcastle disease, are all highly infectious and considered to be among the most virulent diseases classified. The dual-capability organisms include some of the mainstays of biological weapons research, including *Bacillus anthracis* (anthrax) and *Pastuerella tularensis* (tularaemia).

In an attempt to clarify the historical existence of state-run anti-animal BW programs, some differentiation is required. It is useful, therefore, to divide the state-run BW programs into those that carried out research on organisms with a limited anti-animal potential, and those that carried out research on organisms that have only an anti-animal potential. There have been eight BW programs over the last century whose existence is generally accepted in contemporary literature and for most of which there exists documentation in the public sphere: Britain, Canada, Germany, Iraq, Japan,

**Table 1**
**Common Anti-Animal Biological Agents and Their Characteristics**

| Disease | Micro-organism | Most common host organism | Vaccine | Treatment | Notes |
|---|---|---|---|---|---|
| Anthrax | *Bacillus anthracis* | Herbivora | √ | Antibiotics (Penicillin) | Cutaneous, intestinal, or respiratory infections. Death caused by an exotoxin. Multidrug-resistant strain developed. |
| Glanders | *Pseudomonas mallei* | Equines | √ | Antibiotics (Sulphonamides) | Same three channels of infection as anthrax. Nasal lesions and ulceration. |
| Plague | *Yersinia pestis* | Animals, fowl, fish | √ | Antibiotics (Streptomycin, Chloramphenicol, or Tetracyclin) | Bubonic plague, pneumonic plague, or septicaemic plague. Fatality rate: 25%-100%. |
| Foot-and-mouth disease | *Aphthovirus* | Cloven-hoofed animals | For some types | None | Highly infectious via inhalation or ingestion. Fevers and vesicles on mucous membranes. Not usually fatal. |
| Tularaemia | *Pasteurella tularensis* | Ticks | | Antibiotics (Tetracyclins, Streptomycin, Chloramphenicol) | Septicaemia in sheep, pigs, and calves; causes fever and oedema in horses. |
| Rinderpest | *Morbillivirus* | Cattle | √ | None | Pigs also susceptible. High mortality rate. Infection via aerosol inhalation. Fevers and anorexia. |
| Newcastle disease | *Paramyxovirus* | Chickens, turkeys, pheasants | √ | None | Highly infectious via aerosol inhalation. Loss of appetite, discharge from nose, mouth, and eyes, and neurological indicators. Mortality ranges from 0–100%. |
| Avian influenza | *Myxovirus influenzae* | Most avian species | √ | None | Wild birds form a natural reservoir. |
| Brucellosis | *Brucella spp* | | | Antibiotics (Tetracyclin, Streptomycin) | Causes abortion. Infection via mouth, vagina, or wounds. |
| (in cattle) | *B. abortus* | Cattle | | | |
| (in pigs) | *B. suis* | Pigs | | | |
| (in goats) | *B. melitensis* | Goats | | | |
| (in sheep) | *B. ovis* | Sheep | | | |
| (in dogs) | *B. canis* | Dogs | | | |
| African swine fever | *Togavirus* | Pigs | | None | High mortality rates and highly infectious. Hemorrhagic lesions form on internal organs. |

South Africa, USA, and USSR/Russia. All of these programs have carried out research on anthrax as well as other zoonotics. Although direct evidence does not exist that they all carried out anti-animal research with zoonotic diseases, all of these programs had the capacity to use these microorganisms, which might have been part of an anti-personnel program, in an anti-animal capacity. The importance of this revelation is not that these individual countries possessed an anti-animal capability, but that they all potentially did. This combined integration of the pivotal role of anthrax research and the anti-animal capability it confers suggests that the great majority of all BW programs contain an anti-animal potential. It has been established elsewhere that the technical problems in weaponizing anti-animal agents are significantly less than for other forms of BW.[2] This would indicate that a country with an anti-personnel anthrax weapon could comparatively easily convert production into an anti-animal weapon. It follows that the countries believed to have clandestine offensive anti-personnel biological weapons programs can all be considered likely candidates to possess a limited anti-animal potential, as long as their research includes zoonotic diseases. These include: Belarus, the People's Republic of China, Egypt, India, Iran, Israel, North Korea, South Korea, Libya, Pakistan, Syria, Taiwan, and Ukraine.[3]

Of the eight major biological weapons programs, almost all contained offensive anti-animal research. The German offensive program that spasmodically spanned the period of both world wars was almost entirely targeted against agriculture. The World War I program is discussed in greater depth later on. During World War II, Hitler limited German BW research to defensive aspects. Documentation exists that this order was breached only three times—first to test the weaponization of FMD, an agent with very little potential as an anti-personnel weapon.[4] The trials took place in either 1942 or 1943 over an island in Lake Peipus in northwest Russia. One possible method of disseminating a BW agent, developed by the Germans, has been described by Geissler. Geissler stops short of stating that this was an FMD test, but it would certainly appear to be a functional, low-technology method of spreading this disease. This test involved:

"…dropping little bunches of grass or hay dipped in glue, gelatin, etc. To make the virus adhere, which has been dried in epithelial particles."[5]

Contemporary reports were confused as to the targets of these tests. The German World War I program is discussed in greater depth later in this chapter.

The British anti-animal program was also conducted during World War II and took the form of the aforementioned "Operation Vegetarian." This project was instigated to provide a possible retaliatory capability to counter the threat of the German FMD research. Contemporary documentation now indicates that this motivation was based upon fears rather than hard intelligence data. It was centered at the Chemical Defence Experimentation Station, Porton Down. The finished weapon took the form of linseed cattle cakes inoculated with *Bacillus anthracis*. These cakes were subsequently destroyed. They are the products of the first biological weapons program to have resulted in the weaponization of an anti-animal agent.

The Japanese anti-animal BW program was contained mainly within Unit 100, officially called the Kwantung Army Anti-Epizootic Protection of Horses Unit, which was predominantly responsible for "plant and animal research for BW."[6] The Japanese anti-animal biological weapons program was typical of the system as a whole. It was based upon trial and error, so it resulted in few casualties, based on the rare documented occurrences of use. Furthermore, it suffered from too little scientific research and as a result proved to be a limited success.

There is very little direct evidence detailing the extent of the US anti-animal biological weapons program. Previous publications indicated that research was carried out at the Plum Island research facility and that tests were carried out in stockyards in Texas, Missouri, Minnesota, Iowa, and Nebraska,[7] as well as a series of defensive tests on Rinderpest at the Grosse Island facility.[8] Anti-animal research is known to have centered on Rinderpest, Newcastle disease, fowl plague, and anthrax.[9] The anti-animal potential of Brucellosis and Glanders was also noted. The Canadian program can be considered to be parallel to both the US and British projects, as all three were run in the context of a tri-party matrix. Russian interests in anti-animal biological weapons predate the world wars. Testimony of Kanatjan Alibekov, now known as Ken Alibeck, the former First Deputy Chief of Biopreparat, indicates that anti-animal research continued until 1990 and was carried out on an unprecedented scale. The core diseases of the program, codenamed "Ecology," were African Swine Fever, Rinderpest, and FMD. Allegations stating that anti-animal agents were used against the horses of the Mujaheddin in Afghanistan appeared in the public domain in 1999.[10] Since then, their credibility has been called into question by several academics and further research in the Russian archives will be necessary before a definitive statement is agreed upon. What is not clear is the extent or fate of any anti-animal program run directly by the former Ministry of Defense. The program was independent of Biopreperat, and no details of it have ever been released. The program's existence is still not universally acknowledged or admitted to. However, an unclassified US intelligence report published in 1977[11] suggests that further Soviet work on the potential of anti-animal warfare involved work on a number of highly contagious viral diseases of livestock. In this connection, investigations are reported to have included the potential of ticks and insects as agents for dissemination of viral vectors.

The South African anti-animal program still remains for the most part undocumented. Contemporary comments made by western intelligence agents do not correlate with the information produced by the Truth and Reconciliation Commission.[12] Contemporary comments described an advanced, technically adroit, ambitious in scope, and well-resourced program, while the commission described a program based on a single project using organisms generally associated with outdated research. There have been suggestions that South African troops used anthrax as an anti-animal agent in Zimbabwe,[13] but these allegations are disputed in much the same way as those concerning the Mujaheddin.

Iraq carried out research on anti-personnel anthrax weaponry, but UNSCOM reported no conclusive evidence of the existence of an anti-animal program. It did report research on camel pox that, when combined with the pre-established offensive intentions of the Iraqi program (the weaponization of anthrax, Botulinum toxin, and aflatoxins), indicates the existence of an offensive anti-animal program for which documentation has never been recovered.

Having established which countries have carried out research in offensive anti-animal biological weapons techniques, it is necessary to examine the way in which these weapons would be used. The literature available predicts that anti-animal BW would be waged on an entirely different level from anti-personnel weapons and to some extent anti-plant weapons. The economic and social repercussions of these weapons facilitate their use as a means of sabotage and reduce the chance that these weapons would be used on a strategic or tactical level. The German World War I anti-animal BW program is a prime example of an international sabotage effort carried out in the manner predicted for its modern equivalent.[14]

The German program consisted of elements in the USA, Argentina, Spain, Rumania, Norway, and France. The program centered around an evolving technical core, which began with the simple wiping of infectious cultures on the mucous membranes of target animals and eventually involved complex assemblies using capillary action to indoctrinate sugar cubes that could then be fed to animals. This demonstrates how potentially simple the weaponization of anti-animal agents is. Organisms for projects within easy traveling distance were produced and cultured in Germany. They were then shipped, either through the use of diplomatic privilege or via a combination of agents and submarines, to their target countries, where a network of German nationals and foreign sympathizers disseminated them. For operations in the USA, a local laboratory was required. The equipment and cultures were smuggled into the country and assembled in the basement of a residential house rented by German agents. If this was possible in 1917, then it is even more so now, with the commonplace availability of basic biotechnological equipment. Having a culture laboratory in the intended target country increases the potential risk of discovery and the logistical losses suffered if that were to occur. The benefits obtained in ensuring supplies of organisms and being able to test and modify pathogenicity might possibly outweigh the aforementioned drawbacks.

The German program of World War I can now be considered antiquated. Its efficiency was never established—some claims stated that BW efforts halted the export of military animals from the Americas to Europe for some considerable time, while counterclaims stated that no more than a few hundred animals died as a result of the German efforts.[15] This program might represent the anti-animal BW capability that might be fairly readily acquired by a developing country in the new millennium. Given the elevated levels of biotechnology in developed countries, it can be assumed that their programs would not suffer from any lack of lateral transmission, infectivity, or pathogenicity.

The consequences of an anti-animal BW attack would influence the political, social, environmental, and economic spheres. An investigation into the susceptibility of UK agriculture to attack by the viruses of FMD was carried out in September 1954.[16] The study determined that the objective of such an attack would be to cause a sufficient number of outbreaks to overwhelm the preventative organization that would result in the disease achieving endemic proportions. Included in the parameters of the study were cattle, sheep, and pigs, as they form the majority of the susceptible animal population in the UK. The target population included in the study constituted 90% of the protein produced in the UK, and the meat derived from them formed 70% of the daily protein intake per head of the population. This protein intake represented one-seventh of the total calorific consumption of the country. Based upon the figures for 1952, in which 578 outbreaks of FMD resulted in 85,000 slaughtered animals, the report concluded that these outbreaks occurred from relatively few foci of infection; in fact, the report concluded that a single infection in a herd was enough to establish an outbreak. Thus, if several hundred foci were to occur over a period of between three and six weeks, the organizations responsible for controlling outbreaks would be unable to cope and the objectives set out above would have been met. To facilitate this scenario, it was established that sabotage techniques would be more efficient than either a strategic or tactical delivery system. It was also determined that the two most likely targets would be cattle markets and their ancillary services or the farms themselves. The limited spread, given the reduced traveling potential of animals on farms, makes the cattle markets the more likely targets.

The investigation also proved that very large scale movement of animals over wide areas throughout the UK was commonplace and that the potential for the spread of FMD from even a limited number of initial foci was almost unlimited. Figure 1 shows the areas that received cattle from six cattle markets during a single week. Figure 2 illustrates the counties that would suffer an outbreak of FMD if each market were to be a focus of infection. In 1954, each of the markets dealt with more than 7000 head of cattle a week.

It was reported that a successful anti-animal BW attack could result in the loss of between 650,000 and 870,000 tonnes of food resulting from the loss of 15% of UK livestock. These losses could be doubled by successive attacks with different serotypes. The 15% reduction would reduce the total calorific intake of the UK population by 3% and the daily animal protein intake per head of population by 9%. The 1954 estimates indicated that the UK would need to import 207,000 tonnes of emergency foodstuffs to make good the losses.

Although the economic impact of an anti-animal BW attack was not assessed in the aforementioned study, more recent figures are available for the USA.[17] In the US, agriculture and its connected industries constitute 13.1% of the gross domestic product (GDP) and represent 16.9% of total employment. Agricultural exports are valued at around $140 billion and account for more than 750,000 jobs. The economic impact of a successful anti-animal BW attack would, therefore, be enormous and have implications for the entire economy of the USA or any similarly developed country—not just for the agricultural sector.

On February 20, 2001, the Cheale Meats Abattoir in Essex, UK, was confirmed to be contaminated with FMD, and 308 pigs and two cattle were diagnosed with the disease. These infections heralded the beginning of an outbreak that was to last several months and continues at the date of writing. By the middle of June 2001, more than a million animals had been confirmed to be infected by the virus, and more than half a million more had been slaughtered in an attempt to limit the spread of the disease.[18] By the end of the first week of the outbreak, six counties had suffered from confirmed infections. This was to rise to 25 by the end of the first month. At the height of the infection, week six, more than 200,000 animals were diagnosed in just seven days.[19] The National Farmer's Union estimated that the outbreak cost more than £250 million per month directly to agriculture,[20] and the Centre for Economic and Business Research estimated that the cost to UK tourism in 2001 will be around £5 billion. By April, concerns were already being voiced on the long-term effects of the culling policy,[21] used to limit the spread of the disease. The burning of the resulting carcasses results in large amounts of dioxins, which pose a threat to the environment, human health, and the productivity of the land. As the official investigations are still ongoing, the eventual effect of these chemicals is as yet unknown. What is certain is that the eventual final cost to the UK will run into the billions and a considerable percentage of its livestock will have been culled. Although this outbreak was almost certainly natural, the effects are devastating. If forethought and preplanning had been involved, it is likely that the repercussions would have been even worse.

The trend to concentrate livestock production, witnessed over the last decade, will only increase the potential repercussions of a successful anti-animal BW attack. Figures produced for the US Department of Agriculture[22] indicate that 78% of cattle are produced on 2% of feedlots, and that 84% of these feedlots can be found in seven states. Similarly, 74% of swine feedlots can be found in nine states.

Predictions published in the Fall/Winter edition of the *Nonproliferation Review*[23] indicate that this situation is likely to get worse. By 2002, the largest 40 pig producers will provide 90% of the market. By 2005, 30 feedlots will produce 50% of finished cattle, and four meat packers will process 80% of animals sent to slaughter. An average poultry farm will have up to several million birds. The higher the concentra-

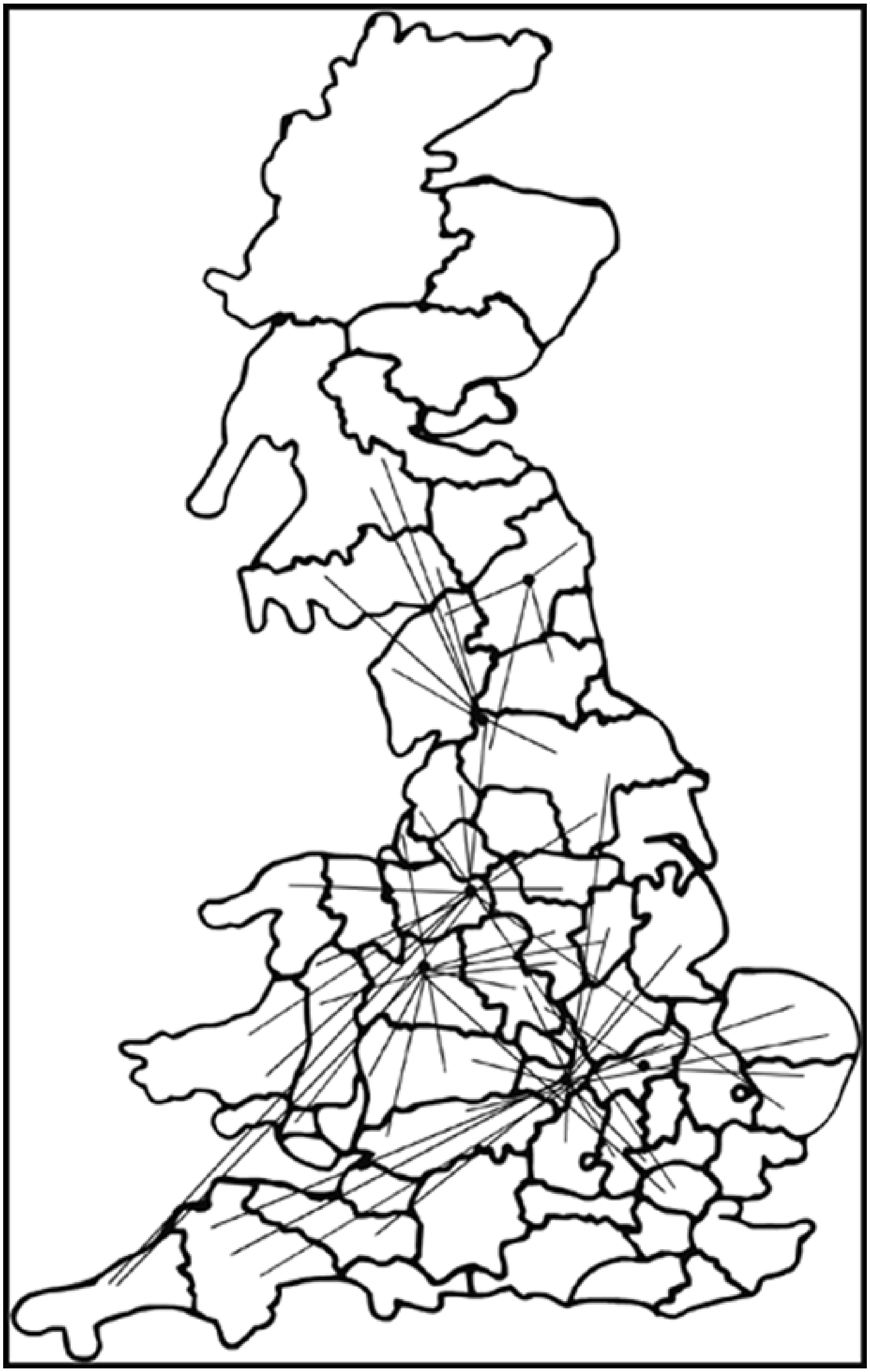

**Figure 1. Weekly stock movements from six markets in the UK.**

**Figure 2. Counties that would suffer an outbreak of foot and mouth disease after infection of six markets in the UK.**

tion of livestock, the larger the potential loss is for a single focus of infection and the greater the incentive to use this form of warfare.

## State Anti-Crop BW Programs

Plant pathogens—disease-producing organisms or entities—that affect food and cash crops can be divided into the following groups: bacteria, mycoplasma and viruses, and fungi.[24] It can be seen from an overview of state anti-agro programs that pathogens appropriate for development as anti-crop BW agents appear to possess certain characteristics. With the exception of some quick-spreading non-soil-borne bacterial diseases, bacterial plant pathogens are most commonly soil-borne pathogens that are capable of spread, sometimes over a number of growing seasons, at only slow rates. Some mycoplasma and viruses are also capable of rapid spread. This is particularly the case where air-borne arthropod (disease-carrying insect) vectors act to facilitate the spread of the disease. However, most diseases that fall into the latter two categories exhibit only slow rates of spread.

The military appears to have emphasized the development of fungal plant pathogens as BW agents. A cursory review of the literature on plant pathology would appear to reveal the reasons for this being the case. First, fungal plant pathogens that affect the aerial parts of plants are known to be capable of rapid spread from initial foci of infection to epidemic proportions within a single growing season. Second, while the spread and intensity of the epidemic are dependent upon a number of related factors such as the virulence of the pathogen, the susceptibility of the plant, exacting environmental conditions including subtle changes in light, humidity, and temperature, and human activity, fungal plant pathogens have been responsible for causing massive and devastating natural disease outbreaks in some of the most important food and cash crops. Modern crop-production practices involving large-scale monocultures of genetically uniform plant types are particularly susceptible to large-scale outbreaks of plant disease involving fungal plant pathogens.

Perhaps the best-known case of a fungal plant disease outbreak in crops resulted in the calamitous Irish potato famine that occurred in 1845-46 caused by *Phytophthora infestans,* the causal agent of late blight of potatoes. More than one million people are reported to have died in the resulting famine and in the aftermath, more than two million people are estimated to have emigrated from Ireland to North America and Australia. In spite of developments in agricultural extension services (disease monitoring, surveillance, and control services) in advanced industrialized countries, this pathogen is reported to have developed a new strain (US-8) that has in the late 1980s and early 1990s, according to Fry and Goodwin,[25] "…re-emerged as an important disease in the US and Canada."[25] While it was reported that the short-term solution to this problem was to be found in the application of fungicide, the development of naturally resistant strains is seen as a long-term solution to the new strain of this pathogen. However, according to the *Guardian*[26] newspaper, "[i]t could be up to 15 years before plant scientists develop new strains of potato resistant to the blight."

Other fungal plant pathogens have been responsible for losses in crops of social and economic significance. Between the 1840s and the 1880s, fungal disease outbreaks caused significant outbreaks in grape crops in Europe. Coffee rust was responsible for the destruction of the entire South East Asian coffee crop in the late 1880s. One of the main causes of the Bengal rice famine in 1943 was the causal agent of brown spot of rice. Fungal plant pathogens continue to be responsible for frequent world-wide epidemics in food and cash crops running into billions of dollars. The world-wide production of rice, wheat, and other cereal crops and their importance as a source of food for millions place a particular significance on the pathogens that cause disease in these crops. According to Rogers,[27] such pathogens "must rank as the most important of all diseases of crops."

It would follow then that fungal plant pathogens affecting food and cash crops would be those that have been the subject of investigations in offensive anti-crop BW programs. If one looks at both the mid-20th century state-run anti-crop BW programs and perhaps more interestingly, at recent state programs about which information has only recently begun to emerge into the public domain, fungal plant pathogens were selected as anti-crop BW agents.

While the German program was concerned mainly with sabotage operations that targeted draft animals en-route to allied forces in the European theater in World War I, there is limited evidence suggesting that post-harvest animal feed was also targeted during the course of this campaign. Additionally, although it would appear that the attacks were never carried out, according to Hugh-Jones,[28] plans to contaminate crops with the wheat fungus *Puccinia graminis* were approved by Berlin, and spore cultures were sent to Buenos Aires, Argentina.

Investigations into offensive aspects of anti-crop BW were conducted by France at Le Bouchet between 1938 and 1940. French investigations concerned the use of potato-eating Colorado beetles and investigations into the offensive use of *Phytophthora infestans*, the causal agent of late blight of potatoes. Offensive German BW research did not get underway in World War II until 1942. Armed with knowledge of French investigations into BW, German BW concerned both defensive and offensive anti-personnel, anti-animal, and anti-crop investigations. Although Hitler's prohibition on offensive BW was repeated on at least two occasions, limited offensive work did take place[29] with considerable work being done in Germany in identifying parasites and plant infections as potential anti-crop agents for use against England and the US. Particular emphasis was placed on investigations into the use of fungal plant pathogens to attack both potato and wheat crops, and investigations into methods of dissemination involved the use of fungal plant pathogens mixed in combination with talcum powder.

It was noted in the section above dealing with state-run anti-animal BW programs that Japan also conducted investigations into the potential use of plant pathogens against crops. According to Williams and Wallace,[30] Unit 100 produced and stockpiled in excess of 100 kg of red rust fungus. Although Japan is the only World War II belligerent known to have conducted offensive wartime operations with BW agents directed against humans, it is not known if anti-crop agents were deployed by Japan during the course of its campaigns.

Wartime collaboration among Canada, the UK, and the US began in the early 1940s with both the UK and the US conducting laboratory-based research into the potential effectiveness of fungal anti-crop BW agents. In the UK, basic research with such pathogens continued at a low level throughout the war and during the post-war period; the UK emphasized the development of biologically active chemical anti-plant agents (commonly referred to as herbicides). In the US, work with BW anti-plant agents received considerable attention. During the course of a program of research and development (R&D) into agents and munitions that stretched from World War II to 1969, the US standardized a number of fungal plant pathogens and weapons systems for use in anti-crop warfare. The identities of only two such pathogens are known: considerable quantities of the causal agents of rice blast (900 kg) and stem rust of wheat (36,000 kg) were stockpiled in the US. Large-scale production techniques were devised for the wheat rust pathogen. Once harvested from contaminated crops, the spore of the wheat rust pathogen measured some 15 by 25 microns (considerably larger and easier to handle than lung-retention-sized particles required for anti-personnel agents). It was then subject to a drying process, and methods were gradually devised to increase daily production and extend the storage half-life and subsequent infectivity of the pathogens. In the case of the wheat rust pathogen, previously classified British documentation[31] revealed that in the US a daily production capacity of 420 lb of dried spores could be achieved. In regard to storage half-life, methods were devised such that this pathogen could remain viable in storage for periods of between 12 months and three years, the latter requiring re-hydration in order to induce germination.

In the case of the rice pathogen, this hardy spore-forming organism measuring between 10 and 20 microns proved to be resistant to both the drying process and adverse weather conditions. Methods were devised for growing this agent on steeped corn under factory conditions. In excess of 100 lb of this agent could be produced per day, and viability in storage could be maintained for periods of up to two years. Further work was done in the US on devising methods for the dissemination of the causal agent of potato blight. In this connection, pellets of porous material were used as carriers for this agent, but investigations proved this not to be a satisfactory method of producing and disseminating this pathogen on a large scale.

R&D continued into the 1950s with US BW workers developing munitions such as the propaganda leaflet bomb and the balloon bomb. Both munitions were weaponized with an agent/feather mix. Testing with such munitions revealed that epiphytotics could be established over wide areas from few initial foci of infection. Developments continued throughout the 1950s and into the 1960s with more sophisticated munitions in the form of line-source spray tanks of the kind used for the dissemination of chemical anti-crop agents. According to one commentator,[32] one such munition might be capable of initiating a plant disease epidemic over an area greatly in excess of 1000 km$^2$.

Cold war targets replaced Axis war-time adversaries, and theoretical vulnerability assessments were applied to scenarios for attacking the food crops of the former Soviet Union and China. Previously classified US documentation[33] estimated that approximately 72% of calorific intake per capita per day in the former Soviet Union was made up of grain. It was estimated that 30% reductions in body weight could be achieved over a period of 12 months, with mortality and death from starvation increasing significantly. Further declassified documentation estimated that an attack on Russian grain might "cripple the USSR in eighteen months."[34]

US military investigations into offensive anti-crop BW halted in 1969 with the unilateral renunciation of offensive BW research and development by President Nixon. The agents and munitions never saw use, and the stockpiles were destroyed in the early 1970s. More recently, however, concern has been raised over the proliferation of this form of warfare. Developments in two state-run programs, those of Iraq and the former Soviet Union, are of particular significance. After five years of investigations into Iraqi ballistic missile, chemical, and BW capabilities, the United Nations Special Commission (UNSCOM) on Iraq announced in 1995 that considerable work had been done in Iraq on acquiring a capability to wage BW against crops. Although the details still remain sketchy, fungal plant pathogens were harvested by Iraqi BW workers from large quantities of contaminated grain. The pathogen in question – again another fungal plant pathogen – was described by UNSCOM as the causal agent of "wheat cover smut," caused by fungi of the genus *Tilletia*. This pathogen is known to be the cause of crop losses in wheat in many parts of the world. Additionally, a limited amount of testing with this agent is thought to have taken place. However, it is not clear if this pathogen was ever weaponized by Iraq.[35]

Details relating to the offensive BW program in the former Soviet Union have not been independently verified. However, Ken Alibek, a former senior official in the Soviet offensive program, reports[36] that anti-crop warfare began in the late 1940s or early 1950s and concerned investigations into producing three fungal plant pathogens as anti-crop warfare weapons: wheat rust, rice blast, and rye blast. In contrast to the sophisticated production techniques associated with the production of anti-personnel agents where weapons designers have to overcome the problem of producing aerosolized clouds of lung-retention sized particles of dangerous micro-organisms such as anthrax, according to Alibek, "…anti-agricultural weapons were generally produced by more primitive methods. For the anti-crop fungal diseases [he states], this generally involved basic surface cultivation techniques." Further to Alibek's claims, an unclassified Defense Intelligence Agency report[37] gave an indication that offensive Soviet anti-crop biological weapons activities had progressed beyond the development of fungal plants, to investigations into the military utility of a number of plant viruses affecting barley, maize, potato, thorn-apple, and tobacco. In regard to the scale of the Soviet offensive program, one US report[38] released in 1999 estimated that approximately one-third of the former Soviet Union's 30,000 BW workers were involved in work on "agriculturally-related issues."

## Conclusions

We have attempted to provide an overview of state-run anti-agricultural programs. In the case of livestock, we have argued that a range of countries exists with the capabilities to use anti-animal biological weapons technologies. Indeed, we have shown that actual use of anti-animal BW has occurred, albeit in World War I. Additionally, we have argued that production of anti-animal agents, when compared with the production of anti-personnel agents, is relatively less complicated. In combination with an increasing incentive to develop capabilities in this field and the increasing integration of biotechnology into everyday life, anti-animal BW must be considered a potentially "high-consequence, high probability"[39] occurrence. It appears that the only restraint placed upon nonstate actors is their own moral code. If the will to pursue this type of attack was to appear, it seems that the technical difficulties placed in the path of the perpetrators would be significantly less than for any other form of mass destruction.

Like anti-animal agents, we have attempted to show that in the case of anti-crop weapons, agents were produced in state-run programs from unsophisticated techniques. Although these weapons were never used, in the case of the US, investigations suggested that plant disease epidemics could be initiated from a limited number of foci of infection. It will be viewed with some alarm that recent examples of proliferation of this form of warfare have been independently verified, and anecdotal evidence suggests that developments in anti-crop BW continued in the former Soviet Union until the early 1990s. A systematic analysis of all state-run anti-animal programs is urgently required to further the public understanding of this relatively obscure but potentially devastating aspect of BW. However, in regard to state-run anti-crop BW programs, a thorough analysis[40] of such programs has revealed that all known state-run BW programs have looked closely at the military utility of BW against crops. Indeed, this latter analysis may have far-reaching implications for current and future state-run BW programs.

While it is to be hoped that the likelihood of both of these forms of warfare will be minimized by a strengthened international legal prohibition against BW, a note of caution must be sounded in a world where incidences of asymmetric warfare targeted against the developed nations are becoming more commonplace. These forms of warfare pose a threat to all countries and their use either by state or nonstate actors could have repercussions for international peace and security.

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   *"When using pathogenic fungi of plants, one need not worry about creating a respirable aerosol; by simply spreading the agent over the target hosts several infections can be induced. Cattle can be infected by FMDv* [Foot and Mouth virus] *simply by coming in contact with the clothes of a contaminated herdsman."*

   He continues that terrorists "could use biological agents that are highly communicable among their non-human targets," first as they may not be concerned about where the disease spreads, as may be the case if these weapons were utilized by an environmental group intending to damage the capitalist forces of globilization. Second, there is minimal risk that these diseases would spread back to a state-sponsor of these activities.

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# The Political Terrorist Threat to US Agriculture and Livestock

2

*Peter Chalk*

## Introduction

Considerable analytical attention has been devoted to the issue of mass destruction terrorism in the US, particularly since Aum Shinriyko carried out its now infamous sarin nerve gas attack against the Tokyo subway system in 1995. However, bio-warfare against agricultural production is one area that has largely been ignored in this policy debate. This is a product of a mindset in the industrialized West that has traditionally downplayed the importance of the rural sector in general. In countries such as the US, Canada, the UK, and Australia, where agriculture accounts for roughly 11 percent of disposable income, food tends to be equated with supermarkets and the local grocery store, not farms, and is always in bountiful supply. The possibility that this highly valuable commodity might somehow be deliberately sabotaged at the source is something that the majority of people simply do not consider, let alone demand action against, as food scarcity has never been an issue for them. It is only in those rare cases where the daily lives of individuals have been directly affected by crop and livestock disasters, such as the "mad cow" epidemic in the UK, that we begin to see the stirrings of any public appreciation for the susceptibility of agricultural produce. However, even in these instances, the tendency has been to place the blame for catastrophes on ineptitude rather than vulnerability.

Of perhaps greater importance, however, have been the twin assumptions by security analysts that terrorists tend to be pre-occupied with human targets and remain tactically conservative. The first supposition stems from a belief that the best way to achieve a general state of societal destabilization and dislocation, not to mention publicity for a cause, is by victimizing civilians with apparently random and highly visible acts of violence. The second is based on the historical record of terrorism itself, which shows an overwhelming pre-occupation with two main weapons: the gun and the bomb. Terrorism specialists assert that extremists are simply not interested in experimenting with new tactics and options and will be unlikely to deviate from present modalities so long as these are sufficient to accomplish their goals. This latter argument is also often made in support of the idea that terrorists will not seek to use weapons of mass destruction (WMD)—nuclear, chemical and biological—that are both technically more complex and less predictable than conventional methods.[1]

However, there may be reason to question aspects of each of these assumptions. Although an indiscriminate bombing and shooting campaign is certainly one way to achieve a coercive potential, it is not the only one. Infrastructure attacks, if properly executed, can be equally as effective, particularly in an era in which "economics" and interdependence have become both the anchor for and soft "underbelly" of the developed world.[2] Bombs and (especially) guns will not always be the most effective way of carrying out these types of assaults,[3] necessitating at least some experimentation with new tactics and weapons systems. In the case of attacks directed against the agricultural sector—which, despite the relative indifference shown to it, does form a critical infrastructural base for the developed world—such "innovation" may well come to include biological agents. The reason for this, as will be highlighted in the paper that follows, is that WMD attacks against crops and livestock are substantially easier, more predictable, and less risky to carry out than those directed against civilian audiences.

The purpose of this chapter is to expand the current debate on biological and chemical terrorism by assessing the potential threat of agro-terrorism in the US. It will first examine the make-up of the agricultural sector in America, assessing potential vulnerabilities that might exist as a result of specific production and breeding techniques within the country. The chapter will then generate a comprehensive risk and threat assessment by analyzing the capabilities that would be required to translate these vulnerabilities into meaningful attacks and the impact that these would have in terms of social, economic and political stability and general public health considerations. The study will also look at the question of whether biological assaults against agriculture and agricultural production truly fall into the lexicon of terrorist violence and why there have not been more instances of this form of aggression in the past. Finally, several threat scenarios are posited for the US, with the chapter concluding on how the country's agricultural emergency management and response structure might be further improved and augmented.

Because the impact of a major animal disease outbreak has the potential to pose the greater threat in terms of public health and general socio-economic and political stability, the focus of the chapter will be on pathogenic livestock (as opposed to crop) attacks. There will also be an analysis of dangers arising out of the introduction of contaminants at food-processing plants, which can target both animal and nonanimal-related products in addition to involving chemical as well as biological agents. Such scares have the potential to be just as destabilizing as wider livestock attacks.

## The US Agricultural Sector and its Vulnerabilty to Sabotage and Disruption

The agricultural sector is absolutely critical to the health of the US economy, indirectly constituting roughly 2 percent of the country's overall gross domestic product (GDP). One in eight people work in some component of agriculture (more if food production is included), making the industry one of the US' largest employers.[4] Cattle and diary farmers alone earn between US$50 and US$54 billion a year through meat and milk sales, while roughly US$50 billion is raised every year through agricultural exports.[5] The share of produce sold overseas is more than double that of other US industries, which gives agriculture major importance in terms of the American balance of trade.[6]

In total, agricultural cash receipts amounted to more than US$190 billion in FY1999, half of which (US$95 billion) were garnered from livestock and poultry sales. While this figure is significant, it represents only a fraction of the total value of agriculture to the country, as it does not take into account allied services and industries such as suppliers, transporters, distributors, and restaurant chains.[7] The downstream effect of any act of deliberate destruction/sabotage to this highly valuable industry would, consequently, be enormous, creating a socio-economic tidal-wave effect that would be felt by all these sectors, impacting, finally, on the ordinary citizen him/herself.

### *Animal Disease Vulnerabilities*

Unfortunately, the intensive way in which farm animals are reared, bred, and transported in the US has served to inadvertently exacerbate agricultural vulnerabilities in this regard. Most dairies can be expected to contain at least 1,500 lactating cows at any one time, with some of the largest premises "housing" as many as 5,000 to 10,000 animals.[8] The outbreak of a contagious disease at one of these facilities would be extremely difficult to control and could easily necessitate the wholesale destruction of all of the animals—a formidable task. According to Dr. Tom Walton, Deputy Administrator in the US Department of Agriculture's (USDA's) Animal and Plant Health Inspection Service, an infection like foot-and-mouth disease (FMD) could spread to as many as 25 states in as little as five days, simply through the regulated movement of animals between farm and market.[9] If one takes into account that certain livestock movements in the US are unregulated, taking the form of either illegal shipments or the reselling and switching of animals at market, then true rates of dissemination could be even greater than this.[10]

Equally as important is the prevailing practice of auctioning animals through large-scale barn sales. These locations represent an ideal place to introduce contagious viral agents, with most lacking any form of on-site security and/or effective bio-surveillance.[11] The probability of intercepting a terrorist seeking to disseminate intentionally a disease agent at one of these sales would be minimal, something that US agricultural officials freely admit.[12] Again, the rapid movement of animals would help to spread quickly and effectively any pathogenic agent after it was introduced.

### *General Food Chain Vulnerabilities*

Apart from direct livestock disease delivery and spread, vulnerabilities exist with respect to the general "farm-to-table" food chain, particularly in relation to the contamination of animal and nonanimal products (vegetables, fruits) at rendering, processing, and packing plants. Several thousand facilities exist throughout the country, the vast majority of which are characterized by extremely poor internal quality control—typically only a fraction of the produce that originates from these plants is actually subjected to end-of-line testing and scanning—minimal bio-security, and highly transient, unscreened workforces.[13]

US health officials have identified these locations as ideal sites for the deliberate introduction of food-borne pathogens (such as salmonella and *Escherichia coli*/*E. coli* O 157), toxins (such as botulism), chemicals (such as dioxin), and heavy metals (such as lead or mercury). Facilities primarily dealing in raw/fresh fruits and vegetables and/or aggregated foodstuffs that do not require cooking are deemed to be especially vulnerable, as there is no heating process that can be brought to bear against pathogens or bacteria that may in fact be present. Moreover, because of the rapidity with which products are typically transported from processors to grocery stores—as many as 48,000 heads of lettuce can be on retail outlet shelves within a day of picking in California—tracing contaminated foodstuffs back to their point of origin can be highly problematic.[14] This is particularly so given that most firms lack adequate/accurate record systems and call-back procedures, something that is especially true at the lower end of the production scale. Indeed, in many cases, products may have already been consumed before either companies or authorities actually realize that a major problem is at hand.

The various potential vulnerabilities outlined above can only be considered realistic threats; however, if it can be shown that they exist within a terrorist operational and motivational context, that suggests a reasonably high likelihood of possible exploitation. In turning to this issue, three central questions need to be addressed:

- What capabilities would be required to carry out attacks that have a specific anti-agricultural focus?
- What is the risk potential of developing such a course of action?
- What would be the purpose/impact of carrying out a sustained attack against agriculture?

## Agricultural Attacks: Capability Requirements and Risk Potential

### *Capability Requirements*

Weaponizing biological pathogens to destroy agricultural livestock is a far easier process than creating munitions designed to kill hundreds of people. Several factors account for this. First, there are many more agents that are both lethal and highly contagious to animals than is the case with humans (smallpox, certain strains of influenza, and pneumonic plague being the main ones for humans), many of which are not routinely vaccinated against. At least 22 such diseases are known to exist, most of which are also environmentally hardy—being able to exist for long periods of time in/on organic matter—and reasonably easy to acquire, produce, and use.[15]

Second, livestock, itself, has become progressively more disease prone in recent years as a result of large nonimmune populations that remain vulnerable to diseases for which vaccination is either not practiced or unavailable in the US. Equally as important has been the intensive use of chemically based "growth promotants" designed to elevate the volume, quality, and quantity of meat production as well as meet the specific requirements of potential vendors. These bio-technic modifications, together with increased stockpiling densities, have combined to dramatically elevate the stress levels of exposed livestock, lowering, in the process, their natural tolerance and immunity to disease.[16]

Finally, as noted above, problems of pathogen dissemination have been largely circumvented as a result of the extremely intensive way in which farm animals are currently reared, bred, and transported. Simulations of an FMD outbreak in California's South Valley have shown, for instance, that an initial infection in the San Joaquin and Chino regions could be expected to spread to all susceptible populations in the state in as little as 35 days.[17]

The capability requirements for carrying out a food-borne attack are equally rudimentary, and certainly more so than those that would be required for an air-borne assault. There are a myriad of possible agents and vectors that could conceivably be used, most of which are either readily available or do not require any substantial scientific knowledge to isolate/develop. Moreover, developments in the farm-to-table food chain continuum have increased the number of potential "entry points" for chem-bio contaminants. This has helped to augment the technical ease of disseminating contaminants into animal- and plant-based products, particularly given the relatively low level of bio-security and surveillance that exists at many of the production food-processing and animal-rendering plants. It is also worth bearing in mind that, at least at present, there are few definitive technologies that could be used to detect bio-chem contaminants at food plants in a real-time sense, meaning that authorities would probably become aware of an attack only *after* it has taken place.[18] Possibilities for pre-emptive action are therefore highly limited.

### *Risk Potential*

Quite apart from their relative ease, attacks against agriculture are comparatively risk free in the sense that they do not cross the threshold of mass destruction; nor, in most cases, do they represent a direct threat to those carrying them out. Destroying pig or cattle production would be unlikely to attract the type of unfettered response that a more "conventional" bio-attack against a heavily populated center such as Los Angeles or San Francisco would. Equally, because there is no large-scale loss of human life, perpetrators are unlikely to be affected by residual feelings of moral guilt or, indeed, substantially weakened by reduced popular support—both potential costs of civilian-oriented operations. As Rogers, Whitby, and Dando have observed: "[A]n overt assault against plants [and animals] may be more psychologically acceptable to people and might seem almost benign [in comparison]."[19]

Moreover, biological attacks against livestock can be carried out in such a way that they imitate natural/common disease occurrences, which both complicates accurate epidemiological investigation and greatly reduces risks to the perpetrator(s) of possible detection. FMD, for instance, closely mimics several bovine diseases/conditions (in its initial stages) that are endemic to the US, a quality that any "enterprising" terrorist could exploit to offset suspicions that a foreign animal disease (FAD) had been intentionally introduced into the state. In terms of personal safety, biological agro-terrorism is also more attractive than experimenting with human viral and/or bacterial agents as virulent non-zoonotic diseases such as FMD, hog cholera, and African swine fever (ASF) can be used. While all of these infections are highly pathogenic to ruminant and/or swine animal populations, they cannot be passed on to people and, therefore, pose little risk in the form of accidental or latent infection (unlike Class-A designated agents such as anthrax, plague, smallpox, and tularemia).[20]

Compounding all of these considerations is the simple fact that agro-terrorism is generally not something that the majority of the farming community actively thinks about, let alone prepares for. In terms of contingency planning, most concern centers on changing market and consumer trends and how to safeguard against high-probability events (such as adverse weather conditions), not on how to protect livestock, crops, and related products from deliberate sabotage and destruction.[21] Such attitudinal traits are certainly not confined to farmers. Awareness of the potential threat posed by biological terrorist attacks against agriculture is equally lacking within the mainstream bureaucratic and policy-making community. Indeed, the US agricultural sector is still to be officially recognized as a critical infrastructural node that is vulnerable to attack and needs to be safeguarded through a National Infrastructure Assurance Plan.[22] Equally, it was not until October 1998 that the words "terrorism," "agriculture," and "biological weapons" were officially strung together by the USDA and used in the same conceptual sense when assessing potential vulnerabilities to the industry.[23]

## Potential Impacts of Biological Assaults Against the US' Agricultural Base

Notwithstanding its operational ease, there would be little point in investing time and effort in carrying out attacks against animals and crops if the impact of such action was not likely to be that significant. However, this is where the real potential threat of agro-terror comes in. The ramifications of a concerted bio-assault on the US meat and food base would be far reaching and could easily extend beyond the immediate agricultural community to affect other segments of society.

### *Economic Destabilization*

Perhaps one of the most immediate effects of a major act of biological agro-terrorism would be to create mass economic destabilization, generating costs that could be expected to cross at least three levels:

- Direct economic losses resulting from containment measures and the destruction of disease-ridden crops and livestock. Between 1983 and 1984, for instance, the US poultry industry was hit by a particularly pathogenic strain of avian influenza (AI). Eradicating the disease cost the government US$63 million. A study carried out by the USDA similarly concluded that if African swine fever (ASF) were ever to become established in the country, the cost over a ten-year period would be US$5.4 billion.[24]
- Indirect multiplier effects. The extent of these costs can be enormous. In the UK, for instance, the outbreak of bovine spongiform encephalitus (BSE) in the 1990s cost the British government between US$9 and US$14 billion in compensation paid to farmers affected by the slaughter of their cattle and employees laid off in the dairy and beef industries. This increased national expenditure dramatically widened the UK budget deficit, forcing an increased sale of state-owned bonds in an attempt to raise capital. The combined knock-on effect on the public sector borrowing requirement (PSBR) and the retail price index ensured under-performance in gilt options, higher inflation, and a reduced ability to implement long-term interest rate and tax policies.[25] It appears that the indirect costs associated with the 2001 outbreak of FMD will be just as pervasive, impacting not only the British agricultural sector, but also normally unrelated industries such as tourism. Hotels in the Lake District, for instance, were hit with a massive decline in retail sales as a result of cancellations brought about by the quarantine of farms located in or near this hitherto highly popular holiday destination.[26]
- International costs arising from protective embargoes imposed by major trading partners.[27] Following a devastating outbreak of FMD (serotype O) in Taiwan between March and July 1997, for instance, an indefinite ban was imposed on the country's pork exports, causing Taipei's GDP to drop by a full 2 percentage points almost overnight.[28] Argentina provides an equally good case in point. Following the discovery of a fresh outbreak of FMD in March 2001, a blanket ban was placed on the country's beef exports. Economists have predicted that these embargoes will cost South America's second largest economy US$250 million in lost exports in 2001 alone.[29] Because so many variables are involved, from lost trade revenue to forced layoffs at slaughterhouses and farms, true figures will almost certainly be far greater than this.

Product contamination by substate groups and individuals provides an additional indication of the potential economic damage that can be achieved by deliberately targeting food products. Two cases stand out—both of which have involved substantial losses. The first occurred between 1977 and 1979 when more than 40 percent of the Israeli European citrus market was curtailed by a Palestinian plot to inject Jaffa oranges with mercury. The second took place in Chile in 1989 and involved an anti-Pinochet movement lacing grapes bound for the US with sodium cyanide. Subsequent suspensions of Chilean fruit imports by the US, Canada, Denmark, Germany, and Hong

Kong cost Chile more than US$200 million in lost revenue earnings.[30]

### *Loss of Political Support and Confidence*

A successful bio-attack against the US agricultural sector would also serve to undermine confidence and support in state governance. Successfully releasing contagious agents against crops and livestock would undoubtedly cause people to lose confidence in the safety of the food supply and could lead them to question the effectiveness of existing contingency planning against weapons of mass destruction in general. Although agricultural attacks are far easier to execute than civilian-directed assaults (as is pointed out above), such nuances are almost certainly going to be lost on publics who tend to simplify complex events. People may begin to equate the ability to infect animals with an enhanced capacity to target humans, calling for greater emergency planning in major cities, more stockpiling of vaccines, and increased surveillance of "high-risk" groups (which carries risks in terms of civil liberties). Critics, unfairly and with the benefit of hindsight, would almost certainly demand why the intelligence services failed to detect that an attack was imminent and why the agricultural sector was left exposed. Graphic images of diseased cows and sheep would be propagated by the media and likely highlighted as evidence of the extreme susceptibility and vulnerability of all animal life, including human beings, to deadly pathogens. The combined effect would be to initiate a chain of socio-political reactions/events, which, if not carefully managed, could fundamentally alter the relationship between citizen and government at both the state and federal levels.

The actual mechanics of dealing with an act of agricultural bioterrorism could also generate widespread public criticism. Containing a major disease outbreak would almost certainly necessitate the slaughter of hundreds to thousands of animals. The 1999 hendra encephalitis epidemic in Malaysia, for instance, led to more than 800,000 pigs being shot, while the 1997 FMD outbreak in Taiwan resulted in more than 500,000 tons of pork meat being destroyed. Dealing with volumes of these magnitudes in a politically acceptable manner poses a significant challenge on at least two levels.

Euthanizing large numbers of animals, despite being a scientifically justifiable method to contain viral and bacterial dissemination, would be sure to generate vigorous opposition from affected farmers and animal-rights movements, particularly if such operations involved the destruction of exposed but nondisease-showing livestock and wildlife.[31] The fact that the US has not experienced a major cattle or sheep epidemic in the era of television is extremely important in this regard, as it necessarily means that no visual point of reference has been available to prepare the public for the consequences of containing such an occurrence.[32] The use of government marksmen[33] to massacre half a million head, including those that exhibited no clinical signs of infection, is unlikely to be endorsed as a legitimate form of disease containment.[34]

Indeed, even states that have been subjected to major agricultural disasters can be affected by such dynamics. The UK provides a case in point. The mass depopulation operations initiated to try to stem the 2001 FMD outbreak—many of which targeted seemingly healthy animals—have engendered widespread (and growing) opposition from farmers, politicians (citing government over-reaction), and the public at large.[35] This occurred despite the fact that the country was forced to carry out similar measures in the early 1990s to contain BSE.[36]

Even in the unlikely event that large-scale culling operations were accepted, the actual removal of carcasses would be just as challenging. The quickest and easiest way to dispose of contaminated animal waste is either by burying corpses in landfills covered with quicklime or by incinerating them in pits lined with burning tires. However, utilizing such methods in an ecologically "friendly" manner is only feasible if a small number of bodies need to be dealt with. Burning thousands of carcasses with rubber tires, for instance, would create a huge, smoldering, open fire as well as a highly visible atmospheric pollution problem, both of which would attract widespread popular criticism. Mass burial is likely to be just as contentious, not least because of the risk it would be seen as posing to ground water supplies and the fact that it would render large areas of land essentially unusable for many years (of particular concern to heavily urbanized states). Still, the longer officials prevaricate and leave diseased carcasses out in the open, the higher the probability rises that they will have to act to stem the spread of future infectious epidemics—an equally unacceptable outcome.[37]

Responsibility for carrying out mass depopulation and disposal operations would likely fall to the USDA's Animal Plant and Health Inspection Service (APHIS), working in collaboration with relevant local officials. Authorities at both the federal and state levels have pointed out, however, that they have only limited resources for planning a mass depopulation operation and acknowledge that many important logistical issues have yet to be adequately addressed. Few guidelines exist for how to dispose of destroyed animals, for instance.[38] As noted above, burial may not adequately contain the health threat, while incineration may well result in unacceptable byproducts, particularly if it needs to occur in or near a populated area. Portable air curtain, natural gas, or debris incinerators would probably be advised, as it would, on the face of it, seem unwise to consider transporting diseased carcasses to mass disposal sites. It is extremely doubtful, however, whether these facilities would be able to deal with the volume of animals that would likely result from a mass disease outbreak. The same would be true of attempting to destroy contamination through the rendering of carcasses and the subsequent salvage of the animal product. Certainly this has been the experience of health and agricultural authorities trying to deal with the effects of the 2001 FMD outbreak in the UK, where protective culling operations have resulted in excess of 1.2 million carcasses requiring disposal.[39]

Quite apart from the risk of precipitating civil disturbances, there is also the possibility that mass euthanizing, burning, and incineration operations may well spark latent acts of terrorism by both animal rights and environmental partisans. Such a possibility remains particularly in evidence on the US West Coast, not least because of its history of radical, socially inspired activism as well as the visible presence of openly militant organizations, including the Earth Liberation Front (ELF), the Animal Rights Militia (ARM), and the Animal Liberation Front (ALF).[40]

### *Social Instability*

Beyond immediate economic and political impacts, bio-terrorist assaults against agriculture have the potential to create mass panic and could, possibly, stimulate socially disruptive rural-urban migrations. Several animal diseases are zoonotic in nature, meaning that they have the ability to "jump" species and affect humans. Examples include Japanese encephalitis (JE), Rift Valley fever (RVF), vesicular stomatitis (VS), screwworm myiasis, and swine vesicular diseases (SVD).[41] Should an epidemic of any one of these diseases occur in the US, it could have severe repercussions in terms of galvanizing a mass public scare throughout the state, particularly if human deaths occurred. Terrorists could use this to their advantage, allowing them to create a general atmosphere of fear and anxiety without actually having to carry out indiscriminate civilian-oriented attacks (and "accepting" all this entails in terms of attracting mass reprisals and alienating actual or potential support).

Two pathogenic outbreaks that occurred in 1999 illustrate the rapidity with which such effects can occur and the extent to which zoonotic diseases can impact on the psyche of the ordinary citizen.[42] In the first case, a new zoonotic genus within the subfamily strain of the Paramyxovirinae virus (since termed "Nipah")[43] spread throughout Malaysia's Negri Sembilan province, devastating the region's swine population in addition to claiming the lives of 117 villagers. The outbreak, the main part of which lasted just over a month, caused thousands of people to desert their homes and abandon their livelihoods, with many fleeing as internal "environmental refugees" to shanty towns on the outskirts of Kuala Lumpur.[44] The second instance occurred in New York City and involved an outbreak of West Nile Virus (WNV), which was potentially brought to the country by migrating birds from Africa and the Middle East.[45] The disease, which was previously unknown to the US, quickly spread to humans, several of whom subsequently died as a result of massive heart and liver failure. A major and largely unprecedented public health scare ensued, the dimensions of which were further exacerbated by the epidemiological difficulty (at least initially) of definitively determining the pathogen's type, source, and transmission mode.[46]

A food-borne attack would do equally as well in terms of galvanizing mass panic and general social instability. Because most processed food is disseminated to a large "catchment" area in an extremely short period of time, a single case of contamination could have highly significant ramifications in terms of latent psychological effects. This is particularly so if the source of the problem is not immediately apparent and multiple chronic or acute ailments actually ensue. In 1999, for instance, revelations came to light that eight liters of dioxin had been accidentally mixed into grease commonly used by renderers and animal feed producers in Belgium, which had then been shipped to around 1,000 beef and poultry farms scattered throughout the country. Although no deaths from poisoning occurred, the scandal precipitated a major public health scare, resulting in the immediate withdrawal of thousands of poultry and egg products from shop shelves along with meats with a high fat content such as black pudding, beef suet, ham salad, and minced beef.[47] Within a week most Belgians, fearful of inadvertently eating foods contaminated with the cancer-causing chemical, were reduced to a non-vegetarian diet consisting of only three products: rabbit, lamb, and fish. In commenting on the disaster, the editor of *Le Soir* pronounced: "Une catastrophe. The dioxin contamination food scare has attained [unthinkable] proportions."[48] One should also note the political ramifications of the crisis, which was a major factor in the resignation of the Christian Democrat government, which had been in power for 41 years.[49]

### *Agro-Terrorism as a Form of Blackmail and an Economic Crime*

It should, finally, be noted that the low probability of detecting intentional biological assaults against agriculture also makes this *modus operandi* an ideal and largely risk-free way for terrorists (and criminals in general) to generate or otherwise raise financial capital. One particularly effective way of achieving this would be to create and then exploit fluctuations in the commodity futures market. An attack that severely crippled the US cattle industry, for instance, would be sure to result in a major increase in demand, and corresponding price rise for the products of the country's major beef and milk competitors. Astute perpetrators could take advantage of this by simply investing in appropriate stock shares before carrying out their assault. All they would then have to do is wait for the "natural" economic laws of supply and demand to take effect before cashing in on their elevated dividend premiums.[50]

The potential impact and mechanics of agro-terrorism additionally give this form of aggression a high pay-off in terms of more basic extortion and coercive blackmail. Unlike human-directed biological threats, terrorists would have the advantage of definitively establishing the credibility of their resolve by actually carrying out a large-scale livestock or food-borne attack without, thereby, attracting massive retaliation from governing entities that no longer feel they have anything left to lose. Moreover, given the enormous direct and latent damage that could be inflicted by repeat attacks, both state and federal governments would have a strong incentive to negotiate, a key consideration in any blackmail attempt.

## Is This Terrorism and, if so, Why Have Not More Attacks Taken Place?

The absence of direct physical violence against human targets has prompted certain commentators to exclude agricultural attacks from the terrorism lexicon. However, if terrorism is defined as a psychological act of criminal violence that is designed to destabilize society and influence government policies, then attacks against agriculture certainly should be considered terroristic in nature.[51] As noted above, the ramifications of a concerted bio-assault on the country's meat and nutritional base would certainly be far-reaching and could easily extend beyond the immediate agricultural community to affect other segments of society.

Despite the ease and potentially severe implications of carrying out biological attacks against agriculture, to date only a handful of actual or threatened incidents have occurred, including:

- The use of African bush milk (a plant toxin) by the Mau Mau to affect steers at a Kenyan mission station in 1952.
- A threat by Tamil militants to infect Sri Lankan rubber and tea plantations with nonindigenous diseases in the early 1980s.
- The threat by an ecological group called Dark Harvest to contaminate "appropriate places" throughout the UK with anthrax-laced soil in 1981.[52]

If there are no real technological or psychological constraints to employing biological weapons against agriculture, why haven't terrorists made more use of this *modus operandi*, especially given its potential to cause significant economic, political, and social upheaval? One reason could be that terrorists simply haven't thought through the full ramifications of deliberately targeting agricultural livestock and produce. According to this interpretation, it may only be a matter of time before we see more instances of this type of aggression taking place. As Stefan Wagener, a US microbiologist, observes, the ingredients and recipes for an agro-attack are already in place; the willingness and realization to actually use them are bound to increase sooner or later.[53]

Another possibility may be that deliberate sabotage is traditionally not something health officials have actively looked for when investigating crop or animal disease outbreaks. The implication here is that more acts may have actually taken place than we know about. Animal and plant health officials in Washington concede this as a possibility, acknowledging that in most countries (including the US) the tendency is to automatically assume that disease outbreaks are naturally occurring events. The inevitable consequence has been epidemiological investigations that seldom consider the possibility of deliberate pathogenic introduction.[54] This line of reasoning would obviously hold little relevance for possible attacks carried out by publicity-seeking groups (who would engender more criminal-focused investigations by claiming responsibility for their acts). However, it could have some validity for the anonymous terrorist whose only goal is to cause mass disruption and chaos or achieve economic gain.

Finally, it could be that terrorists consider this form of aggression too "dry" in comparison with traditional bombings in the sense that attacks against crops and animals do not produce immediate, visible effects. The impact, while significant, is delayed, lacking a single point for the media to focus on. Such disruptive terrorism lacks drama: "No lives hang in the balance. There is no bang, no blood. They satisfy neither the hostility nor the publicity hunger of terrorists."[55] In this light, the fact that biological agro-terrorism has not emerged as more of a problem is, perhaps, understandable.

However, it would be wrong to assume that this negates the possibility of a switch to this form of violence. Infrastructure attacks, if carried out effectively, can be just as devastating as more traditional terrorist actions, something that is especially true with regard to agriculture. The mere ability to drive a state's economic and management resources toward stemming incipient epidemics and public health disasters gives both food and anti-animal assaults considerable clout that would be of considerable benefit to any group faced with significant power asymmetries. Moreover, as the WNV outbreak in New York demonstrates, a disease outbreak that actually kills human beings *does* have the potential to make a marked impression and certainly can attract considerable media interest, locally, nationally, regionally, and even internationally. It is also perhaps worth noting that, at least at the nation-state level, the potential viability of anti-crop/livestock agents has long been recognized, reflected by weaponization programs in Europe during World War I, the USSR, the US, and Iraq.

## US Threat Scenarios

There are several ways in which an act of agro-terrorism could occur in the US, using a variety of different causative agents and dissemination methods. However, most experts agree that attacks directed either against the cattle industry—given its economic importance—or instituted via the food chain pose the most serious threat in terms of latent run-on effects and general social disruption and panic.

### *Deliberate Introduction of Zoonotic Diseases*

In terms of assaults against dairy and/or slaughter cows, two discrete threat scenarios are possible. The first would involve the deliberate introduction of a cattle pathogen or parasite that is also infectious to people. The objective here would be to galvanize mass anxiety by engendering fears of an animal-borne epidemic that is capable of "jumping" species to cause human deaths. As noted above, there are several agents that could be used in this regard. However, given its visual impact and regional prevalence, the one that represents probably the most viable candidate is screwworm myiasis. The disease is endemic throughout the tropical and semitropical areas of the world, remaining prevalent in Panama and of at least residual concern in Mexico. It is caused by the Cochliomyia hominivorax (literally devouring humans) maggot, which feeds on the living tissue/flesh of any warm-blooded mammal, including in humans where the host's sinuses and cribiform plate are typically attacked.[56]

The ideal time to introduce screwworms into the US would be summer, when temperatures are most conducive to mating and the rapid transformation of larvae into adult flies (a process that can take as little as seven days at 28C/82F). Infecting cattle would not be problematic as females are able to oviposit eggs (which can number in excess of 400 in a single laying) in a wide range of wounds common to these animals, including tick bites and cuts/lesions caused by castration, de-horning, and branding. An initial infestation could easily spread to urban areas (adult flies can be dispersed simply via the movements of vehicles and possess the ability to travel up to 300 km on wind currents), where it would pose an immediate health risk to both domestic pets and humans.[57] The graphic, flesh-eating nature of the disease would undoubtedly have a resounding psychological impact on the public and, if not quickly contained, could quite easily precipitate a mass, social scare.[58]

### *The Deliberate Introduction of a Nonzoonotic Disease*

A cattle assault could also involve the use of a nonzoonotic microbial agent with the aim of undermining confidence and support in government and/or creating widespread economic disruption and damage. US veterinarians agree that the most likely scenario in this case would involve the deliberate introduction of FMD. Not only is the pathogen highly virulent and contagious, remaining the most transmissible viral agent currently known to medical science. It also has the ability to spread to all cloven-hoofed animals, including wildlife, is nonzoonotic (which reduces the risk to perpetrators of accidental infection), and exists in seven separate serotypes, each of which has up to 14 different strains.[59] This latter point is significant as vaccines against the disease all lack a high degree of cross-variant protection. Controlling a large FMD outbreak would possibly require the destruction of millions of animals and potentially cost billions of dollars.

Obtaining and disseminating a sample of FMD into America would not be difficult. The pathogen is endemic throughout South America and can be transported in any sort of organic matter, including manure (possibly smeared on the bottom of a shoe) and food—both of which could be easily smuggled through major ports of entry such as Los Angeles and New York. Disseminating FMD would be as simple as scraping a viral sample directly on a cow in a remote field or merely introducing one into a silage bin. Because of the disease's highly contagious nature and the concentrated way in which cattle are housed and transported in the US, a multifocal viral outbreak would be virtually assured. Moreover, given the scale of the resulting pathogenic spread, conducting sophisticated epidemiological investigations to establish whether the disease was deliberately caused would be extremely difficult.[60]

### *An Attack Further Down the Food Production Chain*

The third scenario, a food-borne attack, would most probably be carried out for extortion/blackmail purposes, although as the Rajneeshe Cult demonstrated with its salad bar poisonings in 1984, this type of assault would work "just as well" as a form of direct aggression against humans.[61] US federal and state officials concur that two types of facilities represent the greatest threat in this regard: packing plants dealing with fresh fruits and vegetables and small-scale food manufacturers, particularly those specializing in ready-to-eat deli meats and aggregated foodstuffs such as sausage meat.[62] These particular sites are variously emphasized because they lack adequate biosecurity provisions, do not utilize heat in the processing stage (a good "front-end" barrier against pathogenic contamination), or deal in preprepared produce that does not require cooking (a good "back-end" defense against microbial introduction). Agents that are especially emphasized include easy-to-produce bacteria such as salmonella (which can be grown in a domestic kitchen) and *E. Coli* 0157 (which is commonly shed by cattle) or highly potent toxins such as botulism.[63] "Venues" would probably focus on bulk-storage containers in aggregated food plants or vegetable/fruit hydrocoolers, both of which remain especially vulnerable to deliberate sabotage and contamination.[64] The rapidity with which food is typically transferred to shop shelves, supermarkets, and restaurants, combined with the lack of real-time detection technologies and/or recall procedures, means that authorities would probably become aware of an attack only after it has already become a serious problem.[65]

## Policy Recommendations

The US agricultural sector remains particularly vulnerable to deliberate sabotage given the vertically integrated nature with which animals are bred, transported, and sold as well as the lack of effective bio-security that exists in many of the nation's food-processing facilities. Disrupting this vital and vulnerable industry would not only cause considerable economic damage. It would also undermine confidence in the responsible stewardship of much of what is seen as contributing to the "American way of life," from fast-food outlets to clothing, transportation, and entertainment.[66]

Despite this, the US is currently underprepared to deal with agricultural bio-terrorism, lacking funds; personnel; appropriate diagnostic, intelligence, and forensics capabilities; as well as a fully integrated national emergency response plan. USDA officials acknowledge many of these deficiencies, freely conceding that at present they lack the means to deal with the type of multifocal disease outbreaks that would be characteristic of a deliberate terrorist introduction.[67]

Measures can and, indeed, should be initiated to augment the effectiveness of the general agricultural/food response structure in the US. In particular, there is a need for the following:

- Investment in human, physical, and logistical infrastructure, especially with regard to FAD diagnostician training; regular preparedness and response exercises and programs; appropriate diagnostic facilities capable of supporting high-level research into virulent foreign and exotic animal diseases; and integrated electronic communication systems between emergency-management staff and field-response personnel.
- Reform of the overall veterinary science curriculum, with a greater emphasis on large-scale animal husbandry and foreign/exotic disease recognition and treatment.
- Greater involvement by accredited local/state veterinarians in the USDA's overall emergency-management system (which would fulfill an important "force-multiplier" function). This should be accompanied by the institution of a more viable passive disease-reporting system through the establishment of effective field emergency-management center communication channels and the initiation of a dedicated USDA outreach program to ensure that farmers are aware of whom to call in the event of a problem.
- Better-coordinated and more standardized links among the US agricultural, criminal justice, and intelligence communities, especially in the context of epidemiological investigations to establish whether a disease outbreak was deliberately orchestrated or the result of a naturally occurring phenomenon.
- Standardized and integrated emergency-response systems to ensure that all relevant agencies are able to make an adequate assessment of their respective powers, duties, and obligations in response to an animal/plant disease outbreak.
- The establishment of a viable national agricultural insurance scheme that can be used to compensate farmers in the event of a major agricultural disaster (something that would also help to heighten the effectiveness of the passive disease-reporting system upon which the USDA relies).[68]
- More effective bio-security, surveillance, and emergency response at food processors and packing plants, especially those that exist at the smaller end of the scale. Immediate measures that could be usefully initiated include more effective site security, increased background checks on seasonal employees, and the development of clearly documented, well-rehearsed product-recall plans.[69]

Reform along these lines—which would serve the dual purpose of also augmenting the USDA's ability to deal with natural disease outbreaks—will not be cheap and will definitely require federal support. Considerable money has already been devoted to defending against the relatively low-risk scenario of viral and bacterial attacks aimed at human populations. By comparison, contingency measures for livestock and crop protection have attracted virtually no support, despite the comparative ease of carrying out such attacks and the enormous implications they pose for the economic, social, and political stability of the US. Serious assessments of the threat posed by biological terrorism suggest that this imbalance needs to be modified through enhanced federal funding, improved state/local preparedness, and increased national leadership and coordination.

## References


1. Comments made by Ariel Merari during the "Future Developments in Terrorism" Conference, Cork, Ireland, March 1999.
2. Roger Medd and Frank Goldstein, "International Terrorism on the Eve of a New Millennium," *Studies in Conflict and Terrorism 20* (1997): 285. It should be pointed out that some tentative work has been carried out to investigate the possible vulnerability of information infrastructures to terrorist and criminal sabotage. Representative studies include John Arquilla, David Ronfeldt and Michele Zanini, "Networks, Netwar and Information-Age Terrorism," in Ian Lessor *et al*., eds., *Countering the New Terrorism* (Santa Monica, CA: RAND, 1999); Frank Cilluffo and Curt Gergely, "Information Warfare and Strategic Terrorism," *Terrorism and Political Violence* 9/1 (1997); Matthew Devost, Brian Houghton, and Neal Pollard, "Information Terrorism: Political Violence in the Information Age," *Terrorism and Political Violence* 9/1 (1997); and Kevin Soo Hoo, Seymour Goodman, and Lawrence Greenberg, "Information Technology and the Terrorist Threat," *Survival* 39/3 (1997).
3. It needs to be acknowledged, however, that bombings have been used with devastating effect against physical infrastructural targets. A case in point was the Provisional Irish Republican Army's (PIRA) decimation of London's financial heartland in April 1992. The 100 lbs of high explosive that were used to carry out the attack caused more than US$1 billion's worth of damage, severed up to 12,000 telephone cables, and disrupted the operations of at least 36 businesses in 40 buildings. Four years later, another PIRA bomb attack in London's Dockland's area damaged 75 percent of the office space in Canary Wharf, causing damage in excess of US$175 million. See "Shattered City Strives for Business as Usual," *The Financial Times*, 13/04/92; "One Dead, 40 Hurt as Blast Rips Central London," *The New York Times*, 25/04/93; "IRA's Attack Threatens Clinton's Credibility," *The Australian*, 12/02/96; and "Building Repairs to Cost $175 Million," *The Australian*, 12/02/96.
4. Comments made by Noreen Hynes during the International Conference on Emerging Infectious Diseases (ICEID), Atlanta, Georgia, July 16-19, 2000.
5. Ellen Shell, "Could Mad Cow Disease Happen Here?" *The Atlantic Monthly* 282/3 (1998): 92; "Stockgrowers Warned of Terrorism Threat," *The Chieftain*, 19/08/99.
6. Terence Wilson, Linda Logan-Henfry, Richard Weller, and Barry Kellman, "A Review of Agroterrorism, Biological Crimes and Biological Warfare Targeting Animal Agriculture," unpublished paper supplied to the author, 22.
7. *Ibid*., 23.
8. Corrie Brown, "Impact and Risk of Foreign Animal Diseases," *Vet Med Today* 208/7 (1996): 1040; Siobhan Gorman, "Bioterror Down on the Farm," *National Journal* 27 (July 1999): 812;

Agricultural Research Service (ARS), *Agriculture's Defense Against Biological Warfare and Other Outbreaks* (Washington, DC: United States Department of Agriculture, 1961), 2. The level at which eradication becomes unfeasible depends on available technical, economic, and political limits, but is generally considered to be around 1 percent. In other words, once 1 percent of a susceptible population has been infected with an animal disease, eradication is no longer advantageous.

9. Personal correspondence between the author and the US Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) officials, Washington, DC, and Riverdale, Md., 1999-2000.

10. John Gordon and Steen Beech-Nielson, "Biological Terrorism: A Direct Threat to Our Livestock Industry," *Military Medicine* 151 (July 1986): 358. See also E. McCauley *et al*., *A Study of the Potential Economic Impact of Foot and Mouth Disease in the United States* (Washington, DC: US Government Printing Office, 1979).

11. Personal correspondence between the author and USDA officials during the "Future Issues of National Security" Conference, Santa Monica, Ca., February 2000. See also Wilson *et al*., "A Review of Agroterrorism," 26; and Javier M. Ekboir, *The Potential Impact of Foot and Mouth Disease in California: The role and contribution of animal health surveillance and monitoring services*, Internet Release: http://aic.ucdavis.edu/pub/fmd.html, 22.

12. Personal correspondence between the author and APHIS representatives, Washington, DC, July 2000.

13. Generally background checks are conducted only to ensure that workers satisfy Immigration and Naturalization Service (INS) requirements.

14. Only the largest food processors in the US are thought to have in place effective product-recall plans. These firms utilize a "tagging" system that allows them to trace the various components used in their products back to their point of origin. It has been suggested, for instance, that should Heinz discover that one of its cans of tomato soup was contaminated, the firm would be able to trace back the source of the problem to the farm on which the tomatoes were originally grown. Correspondence between the author and officials with the California League of Food Processors, Sacramento, Ca., August 2000.

15. Principal among these are:
    - Foot-and-mouth disease (FMD).
    - Classical swine fever virus.
    - African swine fever virus.
    - Rinderpest.
    - Rift Valley fever.
    - Avian influenza.
    - Newcastle disease.
    - Bluetongue.
    - Venezuelan equine encephalomyelitis virus.
    - Vesicular stomatis.
    - Lumpy skin disease.

16. Comments made by Dr Paul Effler during the "Transnational Security Threats in Asia" Conference, Waikiki, Hawaii, 8-10 August 2000. See also also Corrie Brown, "Emerging Animal Diseases," in W.M. Schield, W. Craig, and J. Hughes, eds., *Foreign Animal Diseases* (Richmond, VA: United States Animal Health Association, 1998), 159.
17. Ekboir, *The Potential Impact of Foot and Mouth Disease in California*, 59-65. This rate of dissemination assumes no depopulation of latent infections and 90 percent destruction of infected herds each week.
18. Comments made by Jannel Kause during the "Bioterrorism in the United States: Calibrating the Threat" Seminar, Carnegie Endowment for International Peace, Washington DC, January 2000. It should be noted that the USDA Food and Safety Inspection Service (FSIS) is currently attempting to implement various bacterial detection technologies; research and development in this area, however, remains at a very early stage and certainly does not come anywhere close to the quality-control programs seen in the pharmaceutical manufacturing industry.
19. Paul Rogers, Simon Whitby, and Malcolm Dando, "Biological Warfare Against Crops," *Scientific American* (June 1999): 72.
20. Class-A designated agents are those that have been identified by the Centers for Disease Control and Prevention (CDC) as posing the greatest potential threat to humans in the event of a bio-terrorist event, given their lethality, contagious nature, and/or ability to cause mass panic and social disruption. They include anthrax, smallpox, tularemia, plague, botulism, and various viruses that cause hemorrhagic fevers such as arenaviruses (Lassa Fever) and filoviruses (Ebola and Marburg).
21. Gorman, "Bioterror Down on the Farm," 813; Nicholas Neher, "Food Terrorism: The Need for a Coordinated Response—the Wisconsin Experience," unpublished position paper prepared for the USDA's Agricultural Resource Management Division, (n.d.a), 6-7.
22. In May 1998, Presidential Decision Directive (PDD) 63 on Critical Infrastructure Protection was passed. The document designated eight physical and cyber-based systems essential to the minimum operations of the economy and government that were vulnerable to possible terrorist attack or other forms of deliberate disruption. Such sectors were taken to include banking and finance; transportation; electricity, gas, and oil; telecommunications; emergency law enforcement; government services; emergency fire; public health service; and water supply. These various sectors are safeguarded by a National Assurance Plan that:

- Assesses the vulnerabilities of each sector.
- Recommends and institutes measures to eliminate such vulnerabilities.
- Identifies ways in which to prevent attempted attacks.
- Develops plans for alerting, containing, and rebuffing attacks in progress.

See "The Clinton Administration's Policy on Critical Infrastructure Protection: Presidential Decision Directive 63," White Paper, May 22, 1998, 1-3.

23. Comments made by Defense Intelligence Agency (DIA) and USDA officials during the National Research Council "National Security Implications of Advances in Biotechnology: Threats to Plants and Animals" Planning Meeting, National Academy of Sciences, Washington DC, August 1999.
24. See C. Renlemann and Spinelli, "An Economic Assessment of the Costs and Benefits of African Swine Fever Prevention," *Animal Health Insight* (Spring/Summer 1994).
25. "Cost of UK 'Mad Cow' Measures Likely to Widen Budget Deficit," *Associated Press*, 25/03/96;

"'Mad Cow' Could Wallop British Economy," Associated Press, 26/03/96.

26. See, for instance, "Spring Has Arrived, but not for Tourism," *The Washington Post*, 15/03/01.

27. It should be noted that the legal nature of most US export treaties stipulates provisions that allow the country's principal trading partners to automatically institute wholesale export bans in the event of both minor and major foreign animal disease (FAD) occurrences. In effect, this means that even small-scale or, indeed, isolated pathogenic outbreaks are able to cause exorbitant, latent run-on economic effects. A single case of FMD or BSE, for instance, would, under existing export provisions, trigger the same type of formal embargo restrictions that a more generalized outbreak would. Personal correspondence between the author and USDA officials, Washington DC, July 1999. See also "Eastern Oregon Farmers Ready to Eradicate Cattle Disease Threat," *The Oregonian*, 17/08/99.

28. Overall costs of the FMD outbreak ran to US$378.6 million during the four months, including indemnities, vaccines, carcass disposal, environmental protection, miscellaneous expenses, and loss of market value. Personal correspondence between the author and USDA officials, Washington DC, July 1999. See also PC Yang, RM Chu, WB Chung, and HT Sung, "Epidemiological Characteristics and Financial Costs of the 1997 Foot-and-Mouth Disease Epidemic in Taiwan," *Vet Rec* 145/25 (1999): 731-4; Rod Fee, "Armed for Alarm," *Successful Farming* 9/8 (1997): 48; and Frank Fuller, Jay Fabiosa, and V. Premakumar, "Trade Impacts of Foot and Mouth Disease in Taiwan," summary prepared for the Center for Agricultural and Rural Development, March 1999. Accessed through http://www.ag.iastate.edu/card/division/tap/bp16/home.html

29. "Argentina's Concealed Outbreak," *The Washington Post*, 16/03/01.

30. See Ron Purver, *Chemical and Biological Terrorism: A New Threat to Public Safety?* Conflict Studies No. 295 (London: Research Institute for the Study of Conflict and Terrorism, 1996/1997), 13-14; Ron Purver, *The Threat of Chemical/Biological Terrorism*, Commentary No. 60 (Ottawa, Canadian Security Intelligence Service, 1995), 7; David Rapoport, "Terrorists and Weapons of the Apocalypse," paper presented before the "Future Developments in Terrorism Conference," Cork, Ireland, March 1999, 13-14; and "Plant Scientists Sound the Alarm on Agroterrorism," *The Philadelphia Inquirer*, 13/09/99.

31. Brown, "Impact and Risk of Foreign Animal Diseases," 1039; Fee, "Armed for Alarm," 49.

32. Personal correspondence between the author and USDA APHIS officials, Washington, DC, and Riverdale, Md., 1999-2000.

33. US state and federal health officials have recently purchased three captive bolt guns as a contingency plan to achieve mass depopulation of animals; more can be obtained if required.

34. It should be noted that this may not be the case during the containment of a zoonotic disease that is fatal to people. For example, once the Malaysian government determined that the Nipah virus could spread to and kill humans, there was little resistance from the public to mass depopulation measures.

35. Royal Society for the Prevention of Cruelty to Animals..

36 Telephone correspondence between the author and a British Broadcasting Corporation (BBC) correspondent, March 2001.

37. Brown, "Impact and Risk of Foreign and Animal Diseases," 1039. See also Gordon and Beech-Nielsen, "Biological Terrorism: A Direct Threat to Our Livestock Industry," 360.

38. In certain states, such as California, regulations do allow for agricultural officials to order mass depopulation and carcass disposal (in the form of an Emergency Order). Enforcing such meas-

ures, however, will almost certainly require martial law or police powers to enforce.

39. "Mixed Signals Muddle Foot and Mouth Fight," *The Washington Post*, 27/03/01; "Foot and Mouth Epidemic Controlled, British Science Advisor Says," *The Miami Herald*, 20/04/01.

40. In the 1980s, the ALF burned down a laboratory belonging to the California Department of Food and Agriculture (CDFA), causing in excess of US$5 million damage.

41. See, generally, Committee on Foreign Animal Diseases, *Foreign Animal Diseases* (Richmond, VA: United States Animal Health Association, 1998).

42. Comments made during the Centers for Disease Control and Prevention's (CDC) International Conference on Emerging Infectious Diseases, Atlanta, Georgia, July 17-19, 2000. Following the initial diagnosis of West Nile virus (WNV), serious attention focused on the possibility that the disease outbreak was the result of a deliberate pathogenic introduction, particularly given the fact that the infection had no prior history of existence in the US.

43. A.J. Barclay and D.J. Panton, "Hendra," *Vet J* 160/3 (2000): 169. The Hendra Virus, first recognized in Australia in 1994/95, is another zoonotic genus that has been identified in the subfamily Paramyxovirinae.

44. See, for instance, "Malay Troops Slaughter Pigs in War on Virus," *CNN Interactive World News*, 20/03/99; "Pig Borne Epidemic Kills 117," *The Sydney Morning Herald*, 10/04/99.

45. It should be noted that the "jury is still out" on how the disease was actually imported into the US. Other possible transmission vectors that have yet to be discounted include infected humans, pet birds, mosquitoes, and horses all remain possible vectors.

46. Comments made during a special panel on West Nile Virus during the International Conference on Emerging Infectious Diseases, Atlanta, Georgia, July 2000.

47. See, for instance, Rachel Johnson, "Belgium's National Identity Has Been Struck a Mortal Blow by a Health Scare," *The Spectator*, 282/8914 (June 1999): 25-26.

48. Quoted in Johnson, "Belgium's National Identity Has Been Struck a Mortal Blow by a Health Scare," 26.

49. "Belgium's 'Rainbow' Coalition Sworn In," BBC On-Line News, 12/07/99.

50. Personal correspondence between the author and USDA officials, Washington, DC, July 1999. See also "Administration Plans to Use Plum Island to Combat Terrorism," The New York Times, 21/09/99.

51. It is also worth noting that attacks directed against property, involving no human casualties, are increasingly being described as terroristic. This is particularly true in the US where law-enforcement authorities, including the Federal Bureau of Investigation (FBI), routinely designate environmental sabotage as a form of terrorism.

52. See Seth Carus, Bioterrorism and Biocrimes. *The Illicit Use of Biological Agents in the 20th Century* (Washington, DC: Center for Counterproliferation Research, National Defense University, 1999), 73-74, 175; Rohan Gunarantna, War and Peace in Sri Lanka (Colombo: Institute of Fundamental Studies, 1987), 51-52; "Anthrax Soil Claim Doubted," The Times (UK), 10/13/81; and "Ecologists Condemn Soil Dumpers," The Times (UK), 10/16/81. A case also occurred in 1997 involving the dissemination of rabbit hemorrhagic disease in New Zealand, widely thought to be an illegal action taken by farmers to control feral rabbits. While not an act of agroterrorism per se, it is an example of a bio-crime against an animal population.

53. Cited in "US Could Face New Terror Tactic: Agricultural Warfare," The Philadelphia Inquirer,

06/22/99.

54. Personal correspondence between the author and USDA officials, Washington, DC, July-August 1999.
55. See, for instance, Brian Jenkins, "Future Trends in International Terrorism," in Robert Slater and Michael Stohl, eds., Current Perspectives on International Terrorism (London: Macmillan Press, 1988).
56. Personal correspondence between the author and CDFA officials, Sacramento, Ca., August 2000.
57. Committee on Foreign Animal Diseases, Foreign Animal Diseases, 372-76.
58. It should be noted that state biological weapons programs have often involved zoonotic diseases such as anthrax and tularemia.
59. Personal correspondence between the author and USDA officials, Washington, DC, July 1999. The main serotypes for FMD include A, O, C, Asia 1, and Southern African Territories (SAT) 1, 2, and 3. For further information, see Committee on Foreign Animal Diseases, Foreign Animal Diseases, 213.
60. Comments made during the "Agro-Terrorism: What is the Threat?" Workshop, Cornell University, Ithaca, NY, November 12-13, 2000.
61. In 1984, the Rajneeshe Cult contaminated several salad bars in Oregon with salmonella in an attempt to influence the outcome of local elections.
62. It should be pointed out that firms specializing in the production of chicken and turkey meat are generally not highlighted as viable sites for a food attack. This is because these facilities tend to be far more cognizant of bio-hazards given the rapidity with which microbial agents and pathogens can spread through poultry plants.
63. This particular agent is emphasized largely because it is stable, can withstand up to 30-minutes boiling time, retains high potency even when diluted, has high morbidity and mortality, and is easily disguised (botulism has no odor and does not visibly spoil produce). Moreover, the toxin can be grown in relatively rudimentary conditions. Indeed, according to toxicologists at the Department of Human Services (DHS), the process can be achieved merely by storing foods with a low pH balance (such as green beans) in anaerobic, water-based conditions for six months.
64. US agricultural officials appear to believe that the water reservoirs in hydrocoolers used in vegetable/fruit packing plants probably represent the most serious threat in terms of a food-borne bio-attack. Not only do producers consistently fail to regularly inspect these systems; the volume of fresh produce that passes through the coolers is also enormous (hundreds of thousands of tons), meaning that it would be possible to contaminate an extremely large amount of food in one "hit."
65. Comments were expressed by Jannel Kause during the "Bioterrorism in the United States: Calibrating the Threat" Seminar, Carnegie Endowment for International Peace, Washington, DC, January 2000.
66. Thomas Walton, "Overview of the USDA Emergency Disease Efforts," Proceedings of the 1998 Livestock Conservation Institute Annual Meeting, Washington, DC, 1998; Agricultural Research Service, Agriculture's Defense Against Biological Warfare and Other Outbreaks, 1.
67. Personal correspondence between the author and USDA officials, July-October 2000.
68. One potentially useful way to achieve this would be to hold a percentage of livestock and relat-

ed commodity sales in reserve, which could then be released to farmers forced to carry out mass depopulation and eradication as a result of a major pathogenic outbreak. See, for instance, Fee, "Armed for Alarm," 50.

69 The majority of US food processing facilities currently lack definitive product-recall procedures. Indeed, all but the largest plants tend to fail to maintain accurate or, indeed, basic distribution logs, customer records, ingredient/label lists, and flow charts. Personal correspondence between the author and California Department of Health and Human Services (CDHHS) officials, Sacramento, Ca., September 2000.

# State-Level vs. Substate Programs Utilizing Anti-Plant and Anti-Animal BW Agents: Is There a Link?

3

*Milton Leitenberg*

As the question of a possible link between state-level and nonstate actors in the area of agricultural biological warfare (BW) remains at present a theoretical question—that is, there is no publicly available evidence that any nonstate actor has attempted or has contemplated such use[1] –I have attempted to assess the subject by examining six issues, some historical and some theoretical:

- Historical National BW Programs that Included Anti-Plant and/or Anti-Animal Agents.
- States with BW Programs and that Support Terrorist Groups.
- False Allegations of Anti-Agricultural BW Use.
- The Experience of Use of BW Agents by Nonstate Actors.
- Generic Issues of the Feasibility of Use of BW by Nonstate Actors.
- The Precedent of Contemplated Use of Fungal Anti-Plant Agents by States Outside Their Own Borders.

I have also added a brief comment on losses routinely incurred because of animal and crop diseases.

## Historical National BW Programs that Included Anti-Plant and Anti-Animal Agents

### *The Programs*

*Germany, World War I.* In an attempt to interfere with the logistic capabilities of the Allied powers, German agents infected horses with both anthrax and glanders as they were being shipped to Europe from the United States, Argentina, and Morocco, with additional German groups attempting to also affect horses on the continent, in Spain, Norway, France, and Romania.[2] Although some unknown quantity of animals died on their cross-Atlantic voyages, there appears to be no record of the numbers or the causes of their deaths. It is therefore impossible to assess the effectiveness of the BW use. Given that there was no particular note of the mortality, the effectiveness was presumably very low. German military services also planned to sabotage Argentine wheat production using the wheat rust fungus, *Puccinia graminis*, but the orders to carry out the operation were countermanded after the spore cultures reached Buenos Aires.[3]

*France, Late 1930s.* As early as World War I, Great Britain and France had considered the use of potato beetles as a weapon against Germany. In the immediate pre-World War II period, France was engaged in an anti-crop BW research program based on potato beetles. Aircraft release of the beetles was tested. No known use ever occurred. Millet and Whitby also report that French researchers examined the fungal plant pathogen, *Phytophora infestans*, which infects potatoes.[4] The target of the program was clearly a food crop utilized by the civilian population, harking back to the food-deprivation blockades by both sides during World War I. Some research was also carried out on rinderpest virus, with cattle as the target.[5] Germany discovered the details of the French BW program when it overran France in 1939.

*Germany, 1939-1945.* Germany was engaged in an analogous research program based on potato beetles and undertook testing of air-dropped beetles. The target would again have been the opposing side's domestic civilian population, but again no use is known to have occurred. (It seems plausible that the discovery of this program by the USSR at the end of World War II provided the idea for the years of subsequent false allegations by the USSR, Czechoslovakia, Hungary, and the German Democratic Republic (DDR) (East Germany) charging the US with actual use of Colorado potato beetles over Eastern Europe in the 1950s and 1960s (this is discussed in a subsequent section below). Germany also had a program dealing with foot-and-mouth disease (FMD), and thus paralleled the French program of both plant and animal pathogens. Over a period of years during the war, German research management committees dealing with BW also discussed the possibility of looking into the feasibility of the offensive use of a variety of agents, including turnip weevils, Pine leaf wasps, antler moths, potato stalk rot, potato tuber decay, and the use of weeds to attack crops. In some cases, extremely small research programs of little apparent significance were carried out on some of these organisms.[6] It was calculated that 20 to 40 billion potato beetles would be needed to produce even a minimal dent in the British diet, and that there was no capability in Germany to breed such quantities of the beetle. Similarly, a single, isolated comment in a research meeting to the effect that several varieties of fungal pathogens "would have to be used in order to ensure a 50% destruction of crops" has no significance whatsoever as regards a serious offensive BW program.[7]

Orders from higher-level German military and political authorities stated that the research work to be done was to be defensive and forbade offensive BW work. These orders remained operative throughout the war and were an impediment to the interests of several of the individual researchers involved.[8]

However, two things that are of interest are evidence of thought given to distributing agents "by means of sprays from aircraft," based on peacetime methods that had been used for forest protection, and evidence of a very few field trials despite a prohibition against field testing of either simulants or actual pathogens. One test site, about which apparently little or nothing is known beyond its designation, sometimes referred to as "B-feld Ost" (Bacteria Field East/ or Versuchsfeld Ost" (Testing Ground East), existed in Galicia in Eastern Europe. A second test site utilized an island in Lake Peipus, in northwest Russia, and here a single field test using FMD was carried out in October 1942, using 50 reindeer as the target animals. The foot-and-mouth virus was prepared at the Reich Institute for Foot and Mouth Disease, a virus vaccine production facility, and preliminary experiments on cattle were carried out there.[9]

*Japan, World War II.* Japan carried out an extensive campaign of BW use during World War II, primarily in China but apparently also to a lesser degree in other Southeast

Asian countries that it had occupied. However, it never used BW against UK, British, or Australian military forces. Japanese policy on BW in World War II was exactly the opposite of that of Germany. Japanese research started well before the war, scientific proponents were able to obtain high-level military and political support for an offensive program, and use in the field was extensive. One of the three main organizations associated with Japan's Kwantung Army in China that carried out BW work, the Kwantung Army Anti-Epizootic Protection of Horses Unit, later designated as Unit 100, was assigned the responsibility for anti-plant and anti-animal BW. Its nominal title was a cover for the purpose of its main work, which was BW. In his chapter on Unit 100, Harris makes repeated reference to plant and animal BW: "Livestock viruses…nose ulcer, sheep pox, ox plague…viruses that destroy crops…huge quantities of herbicides…sheep plague…BW testing in border areas of Manchuria and Mongolia with assorted animals and different soils and crops…on numerous occasions daring members of the unit crossed the border into Soviet Siberia. Here they carried out widespread sabotage, spreading disease to animals, humans and plant life."[10]

Harris states that "…the unit's principal responsibility was to develop BW weapons useful in sabotage operations." Nevertheless, a reader of the pages comes away with an unclear picture of exactly what the Japanese did in the way of anti-plant and anti-animal BW, and what its results were. At one point, Harris also refers to experiments to facilitate postharvest rot, presumably on the stored crops, using various types of bacteria. (The results of Japan's more extensive anti-human BW efforts again appear to have been militarily insignificant, and the numbers of casualties it produced are strongly disputed by the two major experts on the subject, Harris and Keiichi Tsuneishi.)

In his chapter in the 1999 SIPRI volume edited by Geissler and Moon, Harris's sole entry on plant pathogens is somewhat different, and no mention is made of animal pathogens:

"Considerable work was also undertaken on crop destruction agents: fungi, bacteria and nematodes were studied, particularly for the effects on practically all grains and vegetables, especially those grown in Manchuria and Siberia. Dissemination techniques, however, were only marginally studied although geographical and climatic factors were researched."

There is no mention of actual use, and in a table Harris refers to "poisoning of crops through herbicides" in Jilin Province, Manchuria, in 1940-1941, without any identification of the herbicide used.[11] Williams and Wallace, in a book that parallels Harris' book, state that Unit 100 produced and stockpiled in excess of 100 kgs of red rust fungus, but no mention is apparently made of use of the agent.[12]

*Great Britain/Canada/US, World War II.* British and Canadian work on anti-crop and anti-animal BW agents began well before any in the US during World War II. As early as March 1937, Britain's Microbiology Warfare Committee had produced its first report dealing with foot-and-mouth disease.[13] In 1940, the British government wanted to have an offensive BW weapon to be able to use for retaliatory purposes ready within six months. By December 1941, Lord Hankey reported to the Prime Minister that "field work" had began at Porton, and that "most of the work was related to diseases of animals," and that it was already understood that "the only method technically feasible at the moment is the use of anthrax against cattle by means of infected cakes dropped from aircraft."[14] By December 1942, British work reportedly included the testing of pathogens that could destroy sugar beets, as well as fowl plague.

Work in Canada began in September 1940, and among the topics on which research was begun—strongly motivated by Sir Frederich Banting—was the chemical destruction of field crops, the distribution of pathogens from the air, and animal disease, particularly work on rinderpest.[15] The rinderpest work was from the very beginning undertaken with offensive use in mind, but as the war progressed and rinderpest came to be considered the most dangerous threat to North America itself, the work became more and more concerned with defensive aspects and efforts to develop a rinderpest vaccine. Bryden's book contains an excellent brief description of the early interaction between the Canadian and British programs and the first interest by US military intelligence and scientific advisory bodies in the years before a US program actually came into being in 1942-1943.[16]

Quite extensive information is available on the US BW research-and-development (R&D) program during World War II.[17] Some of the anti-plant and anti-animal pathogens on which work was carried out include the following:

<u>Anti-plant pathogens</u>

- Brown spot of rice (Agent E)
- Rice blast (Agent IR; II)
- Late blight of potato (Agent LO)
- Southern blight (Agent C; CO)
- South American rubber leaf blight
- Wheat rusts and smuts

<u>Anti-animal pathogens</u>

- Rinderpest (Agent R; GIR-1)
- New cattle disease (Agent OE; NE)
- Foul plague
- Foot-and-mouth disease (Agent OO)

Very substantial research was also carried out on a variety of chemical plant growth regulators and chemical herbicides (Agents RR, LN). A pilot plant at Fort Detrick for the production of plant pathogens was not completed until February 1945. Consideration of the use of a chemical herbicide, *Ammonium Thyocyanate*, against Japanese rice crops was made in May and June 1945, but rejected on technical grounds of priority allocation of aircraft for bombing missions. A decision on the possible use of a second chemical herbicide 2, 4-D (LN-8), against Japanese rice crops was to be considered in January 1946, and it appears that initial approval to recommend this had been given if a land invasion of the Japanese mainland was to take place in November 1945.[18] In 1950, Hanson Baldwin wrote that "in July and August 1945, a shipload of US biological agents for use in destruction of the Japanese rice crop was en route to the Marianas."[19] However, the statement in the official US government, post-World War II Merck Report that "Only the rapid ending of the war prevented field trials in an active theater of synthetic agents which would, without injury to human or animal life, affect the growing crops and make them useless"[20] apparently referred to *Ammonium Thiocyanate*.[21]

The Allied World War II BW program did, however, produce and stockpile an anti-animal agent. Although the World War II US-UK-Canadian BW program included plans for a potential use of anthrax as an anti-personnel weapon—the US to produce the agent fill and the UK the bomb—neither the agent nor the bombs were ever produced in 1944-1945, and the project was cancelled before the war's end. Instead, Britain produced 5 million cattle cakes impregnated with anthrax, intended for use over Germany. These too were never used.

*The USSR.* There appears to be no available knowledge as to whether the USSR considered anti-animal or anti-plant BW agents during World War II.

*USA, 1950-1969.* The first production and procurement by the United States of a biological munition after 1945 took place at the end of 1951. The agent was an anti-plant agent, wheat stem rust, code named TX-1, intended for use against the wheat crops of the USSR. The delivery system was the E77 feather bomb. The weapon was ready for use at the end of 1951 and, according to declassified US documents, was subsequently distributed to Strategic Air Command

(SAC) bomber bases,[22] although only 2500 units were available by the end of 1953, and Gen. Curtis Lemay, the head of SAC was reportedly unenthusiastic about BW. (The second BW agent that the United States produced was *Brucella suis* (AB-1), which was not ready until the end of 1954, but was intended for use as an incapacitating anti-human agent.) In the 1960s, the US also weaponized rice blast, intended for use against China.

Between 1951 and 1969, the US reportedly produced and stockpiled 36,000 kg of wheat stem rust, and between 1951 and 1957 an additional quantity of stem rust of rye.[23] Only 900 kg of rice blast were produced and stored by 1966. (This raises questions as to whether there was actually a sufficient quantity of the latter available to have permitted significant operational use.) The US reportedly standardized five anti-crop BW agents, and Whitby and Rogers postulate what the two others may have been.[24] The US developed and produced several munitions for the distribution of these agents and also carried out an open-air testing program, both in the US and overseas. The US animal pathogen program was focused on the development of the agents causing rinderpest and foot-and-mouth disease, but research was also carried out on Newcastle disease virus, on the pathogen that causes *Vesicular Stomatitis* in cattle, on hog cholera, and perhaps on other animal pathogens as well. Anti-animal pathogens were tested in the United States. The US Central Intelligence Agency (CIA) also developed agents for use in covert anti-crop warfare, but virtually nothing more is known regarding that program, the agents involved, or the putative target. According to declassified documents, the BW agent or agents were never used.[25] (This author does not assume that any of these agents were used against plants or animals as the Government of Cuba alleges. (See below.) The United States of course made massive use of chemical herbicides against Vietnamese rice cultivation and Vietnamese forests between 1961 and 1969. (See below.)

*USSR, 1945-1993.* There are three sources of information on the work carried out in the former USSR on plant and animal BW. The first is a declassified 1977 report produced by the US Defense Intelligence Agency (DIA). The agents that it specified were catalogued by Jonathan Ban:

"The former Soviet Union probably had the most innovative and wide-reaching offensive anti-crop and anti-animal BW programs, although the primary focus was on agents for targeting American and Western European crops. On the anti-animal side, the Soviets experimented with FMD, rinderpest, African swine fever (ASF), *vesicular stomatitis* virus, contagious bovine pleuropneumonia, mutants of avian influenza, and contagious ecthyma of sheep. The Soviets successfully used ticks to transmit FMD, avian ticks to transmit the causative agent of ornithosis to chickens, and insects to transmit plant pathogens. On the anti-plant side, work was conducted on wheat and barley mosaic streak viruses, potato virus, tobacco mosaic virus, brown grass mosaic virus (for use against barley, maize, and thornapple), wheat fungal, and brown leaf rust. Viability testing in indoor chambers was conducted on FMD, and as early as 1935, tests were conducted to develop reliable methods of disseminating FMD in combat situations. Lyophilization and vacuum storage experiments were conducted on maize rust, and stabilization techniques for Newcastle disease virus were also discovered. The Soviets were very active in insect rearing techniques and claimed to have built automated mass-rearing facilities that could produce millions of parasitic insects per day. They used radar to follow the migration and release patterns of insects to determine their anti-crop potential, and the dissemination of insect attractants was considered a way of influencing the migration patterns of both natural and deliberately introduced insects."[26]

Perhaps the most significant aspect of

the material summarized in the 1977 DIA report is that all of its sources for the work summarized above come from the open Soviet journal literature and were published as civil research. The report in fact notes that "Treatment of fields and forests by aircraft to control pests, diseases, and weeds in the Soviet Union provides data applicable to offensive agricultural warfare. The aerosolization process provides information on the efficiency of spraying or dispersal devices and on the most efficient methods for dispersal of wet and dry agents under varied climatic conditions. The amount of material, dispersal rate, and particle size are primary factors in the resultant cloud travel, cloud diffusion, and area coverage."[27]

This is certainly true, and all of the work referred to in the DIA report and summarized above can very well be applicable for the military use of the respective plant and animal pathogens as weapons. However, the same would be true of civil research on the same agents in any other country in the world, and it is not at all clear from the DIA report whether military R&D or civil R&D was being summarized.

The second source is Dr. Kenneth Alibek, former Deputy Director of one of the major segments of the USSR's offensive BW program. Two of Alibek's publications are relevant here: his 1999 book, *Biohazard*, and a brief, two-page paper in the 1999 New York Academy of Sciences publication, *Food and Agricultural Security*. Alibek states that work on plant and animal BW was carried out in institutes under the jurisdiction of the USSR's Ministry of Agriculture and that some 10,000 employees at all levels of technical competence—including support personnel—worked in these institutes. Some of these institutes were in constituent republics of the USSR that are now independent states.

"The code name for this program was Ecology, and …it was run by the Ministry of Agriculture's Main Directorate of Scientific Research and Production Facilities. The weapons developed by this agency can be divided into three categories: anti-crop, anti-livestock and combined anti-personnel/anti-livestock. The anti-crop agents included wheat rust, rice blast, and rye blast; the anti-livestock weapons included African swine fever, rinderpest, and foot-and-mouth disease; and the combined anti-personnel/anti-livestock agents included anthrax and psittacosis….

"Also in contrast to anti-personnel biological weapons, anti-agricultural weapons were never produced on a regular basis or stockpiled. Instead, a number of facilities were equipped as mobilization capacities, to rapidly convert to weapons production should the need arise. The main facilities designated as mobilization capacities were located in Pokrov (a viral production facility) and in Almaty, Kazakhstan (a bacterial production facility). In addition, a facility at Vladimir and several labs in Galitsyno were involved in research, development, and pilot-scale production work. Finally, a facility at Otar, Kazakhstan (about 200 km from Almaty) served as a research, development and testing facility." [28]

Alibek also states that he was informed by General Yevstignaev, the head of the USSR Ministry of Defense Directorate responsible for the USSR's BW program, that glanders was used by Soviet troops in 1982 in Afghanistan in an attempt to interfere with the logistics of caravans of mules and camels that were the sole means of transporting munitions and other supplies from eastern Iran over the mountains into western Afghanistan. The effort was reported to have failed, and was therefore discontinued.[29] There is some very tentative additional evidence that the USSR may also have experimented with anti-crop fungal agents in Afghanistan.[30]

The third source consists of two papers by Anthony Rimington, the first of which is unpublished but deals entirely with the Soviet era "Ekologiya" program[31] and a second published paper that includes several of the informational tables from the first study.[32] Rimington identifies the origin of both the anti-crop and anti-livestock BW program with an August 1958 Soviet government decree that established the institutes responsible for carrying out the work within the structure of the USSR's Ministry of Agriculture. Three of Rimington's tables that followed include a list of the Soviet-era institutes involved, the agents that the USSR developed for anti-plant and anti-animal BW and the organizational structure of the system.

A recent report of interviews with former Soviet scientists provided the following interesting information. In recent interviews in Russia and Kazakhstan, former Soviet scientists also disclosed that they had developed weapons specifically aimed at crops and livestock. Sadigappar Mamadaliyev, the director of the Scientific Agricultural Research Institute, now in the Republic of Kazakhstan, said that in Soviet times, his was one of four centers dedicated to developing lethal germs as weapons against foreign crops and animals. "The Soviets here concentrated on cow and sheep pox and blue tongue," he said. "We also cooperated closely with the All-Russia Institute of Animal Health in Vladimir, Russia, which worked on foot-and-mouth disease, and with the Pokrov Institute of Veterinary Virology, which specialized in African swine and horse fevers."[33]

*South Africa, 1980 (?) to 1993.* There is no available evidence indicating that the South African BW program included anti-agricultural agents, despite allegations of anthrax use in Rhodesia (see below).

*Iraq.* The Iraqi BW program included both an anti-wheat fungal agent (cover smut, caused by a genus of Tileta) and camel pox, although it is not clear if the latter was intended as an anti-animal agent or was being used as a simulant for an anti-human agent. Neither agent appears to have been produced in quantity or weaponized.[34]

### *Crop Destruction by Other Means*

During World War II, Germany used fire to destroy crops when retreating from areas of the occupied USSR. As indicated above, the US planned to use a chemical herbicide against the Japanese rice crop in the case that a land invasion of Japan had taken place in 1946. Defoliation using chemical herbicides (2-4D) was initiated by the UK in its campaign against Malaysian insurgents, including destruction of their food crops. The UK also used small amounts of chemical herbicides in Kenya, and Portugal used the same compounds in Angola prior to 1975.

However, the largest use of chemical herbicides both for purposes of defoliation and for extensive crop destruction was carried out by the United States in Southeast Asia. This occurred primarily in Vietnam, but also in Laos and Cambodia under the Ranch Hand program between 1961 and 1969.[35] The US also destroyed stores of harvested crops using fire and toxic chemicals.[36]

### *Evidence of the Transfer of Technology or Personnel*

As regards the former USSR, BW R&D was carried out in the institutes of a substantial number of ministries:

- The Ministry of Defense
- The Ministry of Agriculture
- The Ministry of Health
- Biopreparat, which was associated with the Fifteenth Directorate of the Ministry of Defense until the mid-1980s when it was transferred to the Ministry of Medical and Microbiological Industries.
- The Academy of Sciences.

There is unquestionable evidence that Iran has been attempting to recruit Russian scientists, as well as some in now-independent former Soviet republics, who had previously worked in the USSR's BW program. As indicated earlier, work on plant and animal pathogens was carried out in the institutes of the Ministry of Agriculture in the former USSR. Iran has succeeded in recruiting some scientists who worked in the former Soviet BW program, including some from Ministry of Agriculture institutes.

In 1997, an Iranian delegation visited the All-Russian Institute of Phytopathology in Golotsino, and three of the institute's scientists reportedly did "travel to Teheran" for an unidentified length of time.[37] An invitation to the Deputy Director of the Shemyakin and Ovchinnikov Institute in Moscow "…to visit Iran to discuss possible 'future collaboration'" came from the "deputy chief of a research organization in Iran's Agriculture Ministry" (which would not necessarily mean that the intended collaboration concerned anti-plant or anti-animal pathogens). A more recent press report states that "Iran…continues to recruit such talent (former Soviet BW scientists) with some success, American and Russian officials agree."[38]

As regards the US, in an interview with a US journalist, Dr. William Patrick described an approach to "a then friendly" government that he and several colleagues made after the 1972 closing of Fort Detrick and the US offensive BW program. The US government intervened to stop the contact.[39] Ironically, the government in question was very probably Iran.

## States that Maintain Offensive BW Programs and that Support or Have Supported Terrorist Groups

For more than 20 years since its first appearance in 1979, the US government has released an annual list of "State Sponsors of International Terrorism." This means that such states provide either some or all of the following to the very many groups that they support: training, sanctuary, documents, funding, explosives, or weapons. Of those states that have appeared on this list virtually year after year, no less than five also appear on the list of states that the US government charges have offensive biological weapons programs: Iraq, Iran, Libya, North Korea, and Syria. Of these, Iraq is specifically known to have developed an anti-plant agent.

This issue is germane because even those who admit that producing biological weapons might not be so simple a task for an isolated, nonnational, or terrorist group immediately raise the possibility that such a group could in theory obtain assistance, either in the form of training, technical assistance, or by direct transfer of a usable agent, from a state that does have a biological weapons capability.[40] Nevertheless, there is no known evidence to date that such an event has ever happened, despite an extensive, decades-long record of very substantial assistance to several dozen different terrorist groups. In addition, most government authorities, both US and other, tend to believe that if a state with biological weapons capability did want to make use of such weapons covertly, it would use its own and presumably better trained personnel to carry out the task and would not do so by transferring them to an external *ad-hoc* group. In 1996, the US Defense Intelligence Agency stated that: "Most of the state sponsors have chemical or biological or radioactive material in their stockpiles and therefore have the ability to provide such weapons to terrorists if they wish. However, we have no conclusive information that any sponsor has the intention to provide these weapons to terrorists."[41]

### *False Allegations of Anti-Agricultural BW Use*

A phenomenon that is a scandal of international diplomacy, at the same time as it has received virtually no critical attention from the analytic community, is the large number of fraudulent allegations of BW use since 1945. The overwhelming majority of these were made by the USSR and Cuba against the United States.[42] The most significant ones are the charges made by China, North Korea, and the USSR of BW use by the US during the Korean War, and the long litany of accusations by Cuba of BW use by the United States against it. The Korean War charges have recently been demonstrated to have been fraudulent, on the basis of documents dating from May to July 1953, following the death of Stalin, and obtained from the archives of the Central Committee of the Communist Party of the USSR.[43] These allegations, however, included the charge that US aircraft had distributed four anti-plant fungal pathogens:

- Purple spot fungus of soybeans.
- A wide host range strain of anthraenose, capable of infecting cotton, apple trees, and pear trees.
- Ring spot fungus, causing apple and pear fruit rot.
- An unidentified legume pathogen.[44]

During the period of the Korean War BW charges, the USSR gratuitously added several others. The Soviet press agency, Tass, suggested that an outbreak of FMD in Canadian cattle was caused by the production of the agent by the US, the UK, and Canada, and that the US was experimenting with locusts in Saudia Arabia and throughout the Middle East.[45] This latter charge coincided with the wide incidence of locusts in the Middle East.

The evolution of the potato beetle allegations, beginning in 1950 by European communist states and also made against the United States, provides an extremely interesting historical story. Geissler states that as early as World War I British and French authorities had thought of the use of potato beetles, with Germany as the target.[46] Potato beetles then appeared as the centerpiece of pre-World War II French BW considerations, and research on them was taken up in the German WWII BW R&D program. In May 1942, German intelligence reported that the US had shipped 15,000 potato beetles to the UK with the intention of using these against Germany.[47] However, the "intelligence" was incorrect: at no time had the US World War II BW R&D program concerned itself with potato beetles. Further, in September 1944, a member of German military intelligence reported that US aircraft were actually dispensing potato beetles over Germany.[48] It is unknown what the source, or ostensible basis, for either of these pieces of misinformation was.

During the years of Soviet occupation of Eastern Europe, there then followed a lengthy campaign alleging that the US was dropping potato beetles on East Germany, Poland, Czechoslovakia, and Hungary.[49] In the DDR, these allegations were supervised by an "Extraordinary Commission for the Fight Against Amikafer"—"Amikafer" or "American beetles" were used synonymously with Colorado Potato Beetle—and included an extensive public mobilization campaign.[50] But it was all a fraud. In 1950, there is a record of exchanges dealing with the alleged "Amikafers" at the very highest levels of the government of the DDR,[51] while in 1981 a thesis presented to the East German Ministry of State Security (Stasi) refers to the "Amikafer" in a single thin paragraph composed entirely of a quotation from a DDR government spokesman in June 1950, directly following the reference to the example of the false German intelligence in 1944.[52] No other "evidence" was provided.

In 1972 the news agency of the Vietnamese National Liberation Front charged that the US military aircraft had dropped plastic bags containing insects over the South Vietnamese province of Quang Ngai in July 1972 in an attempt to destroy rice crops. The insect was reported to be similar to a local type, and had allegedly consumed two-thirds of the rice crop in the Son Ha district of the province.[53] In 1999, Lt. General Valentin Yevstignaev, who had headed the 15th Directorate of the General

Staff of the USSR's Ministry of Defense, responsible for the USSR's biological weapons program until 1992, and who, between 1992 and 2001, headed the renamed but little altered body, claimed that the "mass emergence of Colorado beetles in Russia is due to foreign delivery."[54] And in July 1999 no less a figure than Saddam Hussein accused a New Zealand citizen in the employ of the United Nations of breeding and planting locust eggs to harm Iraqi crops, on behalf of the intelligence services of foreign states.[55] The charge was accompanied by other more ambiguous accusations of biological warfare against Iraq by the United States.

The Cuban charges list no less than 18 separate allegations of BW use between the early 1960s and 1998 in all categories: pathogens against humans, plants, and animals, and multiple instances of each. These are all assumed to be fraudulent. The anti-plant and anti-animal charges include the following agents: sugar cane rust, tobacco blue mold, African swine fever, Newcastle disease, insect pests such as the black plant louse, coffee borer, Thripps Palmi, two bee diseases (Acariasis and Varroasis), black sigatoka (attacking bananas), and others including an unidentified agent that allegedly killed "Cuban" sea turtles.[56] There is substantial internal evidence from within Cuba that even Cuban government ministers understood that the reasons for the outbreaks of these animal and plant diseases, as well as the human diseases that the Cuban government officially attributed to US BW (most prominently Dengue fever), were of natural origin.[57]

Most recently, the Marxist FARC (Revolutionary Armed Forces of Colombia) have charged the United States with biological warfare following the aerial spraying of a chemical herbicide, Glyphosate, in the effort to destroy coca plant cultivation. The charges were a particularly exotic melange: accusing the United States of "a criminal biological war against the insurgents that seek to apply secret US techniques, similar to those used in the 1960s to attack the Vietnamese and Cuban people," pathologies caused by "even unknown insects," and "several diseases still not classified," affecting animals as well as humans, tropical diseases, and finally the postulation that Tularemia, Plague, Smallpox, Brucella, and Leishmania might also be among the pathogens being used against them.[58]

Of course, it was to be expected that the outbreak of FMD that struck cattle and sheep in the UK and reached Europe would produce allegations of purposeful release:

- The *Sunday Express* wrote that "the foot-and-mouth outbreak could have been started deliberately by someone who stole a test tube of the virus from a laboratory…a container of foot-and-mouth virus went missing from a recent government lab at Porton Down in Wiltshire two months before the crisis began."[59]
- In the Netherlands, the press carried rumors that a farmer in financial difficulties bought the virus in South Africa via the internet and deliberately infected one of his own animals so that all his animals would be culled and he could claim compensation money from the government.[60]
- The most significant was a United Press International story that was widely published titled," Experts: Plague Could Be Bio-Terror Attack," and quoted consultant Peter Probst, "If you have a conspiratorial mindset you might think the UK is being used as a test." Although he and Dr. Chalk, also quoted, agreed "that there is no concrete evidence at the moment to support the notion that the current outbreak in Britain and other parts of Europe is the result of a terrorist attack, they do not altogether close the door on that possibility…(another) expert, "who asked not to be named, went as far as to point the finger at Iraq."[61]

It is universally accepted by veterinary epidemiologists that the UK and European outbreaks of FMD are of natural origin. The issue has been widely aired in professional veterinary circles, in the UK and elsewhere, and on the Pro-Med web sites. Not a single such opinion, or expert, was canvassed in the UPI article.[62] The UPI item followed the precedent of Richard Preston's notorious *New Yorker* article in 1999. Preston attributed the outbreak of West Nile Virus infections in New York State to deliberate "bio-terrorism" by Iraq.[63] That claim built on several pages in a book, purportedly authored a year or two before by "Saddam Hussein's double," but which was actually a fabrication produced by British intelligence agencies.

## The Experience of the Use of BW Agents by Nonstate Actors

The global historical record of the use of B (and C) agents by nonstate actors has been reviewed in detail in another paper and is summarized here only briefly.[64] That review comprised several parts, some essentially historical and others forming a transition to current assessments. These components were:

- Databases on biological (and chemical) terrorism.
- A brief description of the efforts of the Aum Shinrikyo group in Japan to produce biological agents.
- The potential of terrorist use of biological weapons in the United States.
- The comparison of potential mass casualty biological events with current annual mortality in several public-health categories.

Only some brief comments summarizing the databases are included here. Five extensive databases have been developed and published since 1993. They are summarized in Table 1.

They were prepared by:

- Harvey McGeorge, in a DOD-contracted study, covering the years 1945 to 1994.
- Ron Purver, at the Canadian Intelligence Service, covering the years 1945 to 1995.
- Bruce Hoffman, at the RAND Corporation, covering the years 1900 to 1998.
- Seth Carus, prepared for the National Defense University (US Department of Defense, or DoD), covering the years 1900 to 1999.
- Amy Sands and Jason Pate, at the Monterey Institute, Center for Nonproliferation Studies, covering the years 1900 to 1999. This database has recently been updated to May 2000.

All five are global surveys. Cumu-latively, these databases contain nearly 1000 events in the 20th century in a wide array of categories, extending from hoaxes, threats, consideration or discussion of use, purchase of materials, attacks on facilities, attempts to use, product tamperings, and actual use. All demonstrate the same results:

- There is an extremely low incidence of real biological (or chemical) events, in contrast to the number of recent hoaxes, the latter spawned by administration and media hype since 1996 concerning the prospective likelihood and dangers of such events.
- Those events that were real, and were actual examples of use, were overwhelmingly chemical, and even in that category, involved the use of easily available, off-the-shelf, nonsynthesized industrial products. Many of these were instances of personal murder, not attempts at mass casualty use. The Sands and Pate/Monterey compilation indicated that exactly one person had been killed in the United States in the 100 years between 1900 and 2000 as a result of an act of biological or chemical terrorism.
- Excluding the preparation of ricin, a plant

**Table 1**
**Databases on Chemical and Biological Terrorism**

1. **Harvey McGeorge, 1994, chemical and biological, 201 to 244 instances:**
   Also includes: *Only threatened use
   *Actions against CB-related facilities
   *Actions limited to theft, purchase, or fabrication of an agent, dissemination device, or related material
   Results demonstrate a clear emphasis on low-tech, commonly available chemical, product-tampering, and poisoning.

2. **Ron Purver, 1995, chemical and biological, 92 instances (30 B and 62 C) in five categories**
   *Threatened
   *Attempted to acquired
   *Acquired
   *Attempted to use
   *Actually used
   (1998 and 1999 studies below demonstrate that many reported "instances" are apocryphal.)

3. **Bruce Hoffman, Rand/Aberdeen database, begins with 1968**
   As of 1998, 8000 "terrorist events"; only around 50 "WMD," including radiological

4. **Seth Carus [NDU], August 1998, biological only, "Bioterrorism and Biocrimes"**
   Instances since 1990: used, acquired, attempted to acquire, considered acquisition, threatened to use.
   45 "use," but only 5 since 1960 (omits most hoaxes, but does include some). Great majority of use for individual murder.

5. **Monterey Institute (Amy Sands), 1999**
   520 cases since 1900 to "acquire or use" C, B, R, and N (but includes all reported hoaxes, approximately 350 between 1997 and 1999).
   *"Terrorist" – 44 percent
   *"Criminals" – 56 percent (extortion, murder, other non-political).

toxin that is relatively easy to prepare, there are only a few recorded instances in the years 1900 to 2000 of the preparation of biological pathogens in a private laboratory by a nonstate actor.

It appears that there are no indications over a 100-year period, from 1900 to 1999, of the use of an anti-plant or anti-animal agent by a nonstate actor.[65] The allegation of dispersion of anthrax against cattle during the Rhodesian civil war in the mid- to late 1970s remains unresolved, although the greater part of the evidence available on the question supports the thesis that the outbreak was of natural origin and not caused by human action.[66] If that should turn out to be incorrect, the event would in any case fall under the category of a direct state act—either by the Rhodesian or South African governments, or a combination of the two—and not be an instance of agricultural BW carried out by a nonstate actor. (It is relevant to note that one or both of these states—South Africa and the former Rhodesia—did use an anti-human pathogen in the field, Vibrio cholera.)

There has also been a detailed examination of the two groups that used, or attempted to produce and use, biological agents:

- The Rajneesh used Salmonella typhimurium in salad bars in the Dalles, Oregon, USA, in 1984.
- The Japanese Aum Shinrikyo group attempted to produce and use two agents, Botulinum toxin and anthrax, in Tokyo, between 1990 and 1994, but failed entirely in its efforts. (It was able to produce and use a low-quality grade of the chemical agent sarin on two occasions, in 1994 and 1995).[67]

There are, however, two interesting bits of information in the Rajneesh and Aum stories, and they are both "null information": the absence of evidence of any "leakage" from state BW programs to nonstate BW efforts:

- No evidence was found that the Rajneesh program had included any search for journal literature, declassified reports, etc., that could have provided information pertaining to work that was carried out at Fort Detrick or agents and methods developed in the course of the US BW program between 1950 and 1969.
- Similarly, despite a report by the Japanese police that some 300 books dealing with microbiology had been found on the premises of the Japanese Aum Shinrikyo group, as well as a specific effort by that group to purchase information and expertise from Japanese scientists with whom key members of the group were acquainted, and also from former senior personnel in the USSR's BW program, and clear evidence of the group's expertise in computer systems and the uses of advanced technology, no evidence has come to light that those in the group responsible for its efforts to produce BW agents searched for available information regarding the past US program. Finally, both groups concentrated on pathogens that would act on people and showed no interest in anti-animal or anti-plant agents.

## Generic Issues of the Feasibility of the Use of BW by Nonstate Actors

This subject has again been discussed in greater detail in an earlier paper, and is therefore dealt with only briefly here.[68] Contrary to a massive amount of disinformation purveyed in recent years, it is not a simple matter either to obtain or to prepare human pathogens for use as BW agents. There are five essential requirements that must be mastered in order to produce biological agents:

- One must obtain the appropriate strain(s) of the disease pathogen.
- One must know how to handle them correctly.
- One must know how to grow them in a way that will produce the appropriate characteristics.
- One must know how to store them and to scale up production properly.
- One must know how to disperse them properly.

Four of the five requirements are among the tasks frequently dismissed as "easy." Some experts do emphasize that the last step, aerosolization to the appropriate particle size for efficient inhalation infection, does present difficulties, while still suggesting that the first four steps are simple. That is not correct, and the paper referred to (Ref. 68) provides examples from the experiences of several national biological weapons programs to substantiate these statements. The conditions during preparation and preservation of the prepared agent critically affect the efficacy of its use.

Dr. David Franz presents a relatively similar overall scheme, but then modifies it, particularly as regards anti-animal agents. After requiring "intent" on the part of the perpetrator, he lists "Access, R&D, Scale-up, Production, and Weaponization" as required stages in the process. For "Classical Battlefield Agents," he indicates that four of these—R&D, Scale-up, Production, Weaponization—are all "Necessary and Difficult." If "Highly Contagious Disease Agents" were to be used, these four stages are listed as "Not Necessary," and if "Foreign Animal Disease Agents" were to be used (against domestic animals, not as an anti-human disease agent), he states that the process can be shorted to "Access and Use," reducing the level of complexity and the amount of work necessary to achieve effective use.[69] The assessment of where anti-plant agents fit into the spectrum of ease-to-difficulty as regards the parameters of working with them is somewhat ambiguous. However, a recent American Phytopathological Society release on "Crop Biosecurity" and potential agricultural bioterrorism commented on a list of 24 fungal, viral, and bacterial plant pathogens—including the 12 included for export control by the Australia group—saying that "We assess that most of these pathogens have numerous deficiencies as bioterrorist or BW agents and, as such, may be inappropriate or too difficult to be used."[70]

## The Precedent of Contemplated Use of Fungal Anti-Plant Agents by States Outside Their Own Borders

The British and American governments are currently funding an R&D program at a facility in Uzbekistan that formerly was involved in the USSR's anti-plant BW program to develop a fungal agent that would attack opium poppies. The suggested target for the agent is Myanmar (Burma). US government research on pathogens that could attack opium poppies goes back to work done in the early 1960s. There is now also a suggestion that a fungal pathogen (Fusarium oxysporum) be used to attack coca plants in Colombia. For the time being, the Columbian government has not permitted this, and a chemical herbicide is being used in the coca-eradication program. If the host country itself were to carry out an eradication campaign using a plant pathogen, that could evade international legal questions as to whether the Biological and Toxin Weapons Convention applied or was being violated. However, it is extremely unlikely that the government of Myanmar would do that, or would sanction the application within its borders carried out by another state. The same presumably applies in the Colombian case. As far as this study is concerned, the question is whether such use would stimulate interest and efforts by nonstate actors to follow the same practice against agricultural crops in the US or in the various countries of Europe. The possibility should be taken into account. It is also of interest to note that when the outbreak of foot-and-mouth disease occurred in Taiwan and the Nipah virus in Malaysia, there were suggestions in both cases that the disease outbreaks were not of natural origin. In the Malaysian case, the statements came from senior government officials, with the added innuendo that the United States may have been the responsible party. Although Taiwanese FMD was attributed to smuggling, experts do not otherwise judge either outbreak to have been anything other than natural. One should also note that 75 percent of emerging infectious diseases reach human populations from animal reservoirs.

## Conclusions

The task of this paper was to assess whether there was evidence of any direct or indirect transfer of information, practice, etc., regarding anti-plant and anti-animal BW from national programs to nonstate actors in the past. Given that the only BW program in World War I was an anti-animal program, and that both anti-plant and anti-animal pathogens were very prominent components of several major national programs in the interwar period and during World War II, the possibility has been there for some 80 years. In addition, the US, USSR, and Iraqi BW programs weaponized and stocked anti-plant agents as part of their post-World War II BW programs, and at least the USSR did the same for anti-animal agents. The short answer to the question is therefore "no": there appears to have been no "leakage" whatsoever to date from these national programs to nonstate actors. Beyond "leakage," there appears to have been no instance of anti-animal or anti-plant BW carried out by any nonstate actor, irrespective of the possible source of the idea.

## Addendum

In an earlier paper assessing the general biological weapons threat that a terrorist group or nonstate actor might be capable of, a comparison was made of the numbers of victims in a postulated "mass casualty BW event," with the annual US mortality attributed to a small number of selected routine public health phenomena. Having learned at the end of September 2000 of the near-total loss that year of the tomato crop in Italy because of a sudden virulent outbreak of cucumber mosaic virus (Bromoviridae Cucumovirus), it seemed of interest to make a similar comparison for agricultural pathogens. In the case of the Italian tomatoes affected by the cucumber mosaic virus, it appears that there had always been random, sporadic, and localized outbreaks of the disease. This year, however, it suddenly wiped out tomatoes in virtually all of Italy, with some minor exceptions, and also in a large portion of Spain.[71] It has further become understood that the phenomenon of "new and emerging" viruses also includes plant viruses that attack agricultural crops and viruses that attack domestic animals.[72] One can also note with some irony that the litany of Cuban attributions of BW that itemize its economic losses caused by various plant and animal diseases is nothing more than a documentation of the ravages that these pathogens cause to agricultural production in a developing country, with the added aspect in the Cuban case of very mistaken agricultural decisions taken by the highest political officials.

What, then, is the magnitude of annual global agricultural loss caused by pathogens, the "background" level of natural occurrence? Such a compilation omits two major additional categories:

- The losses caused by postharvest rot and depredation by mammalian and insect pests as a result of poor crop-storage conditions.
- The damage caused by invasive species, which in the United States alone costs an estimated $122 billion annually in control, loss of resources, and damage to property.[73]

Whitby and Rogers note, "...fungal diseases cause losses running into billions of dollars each year throughout the world, especially on cereals, vegetables, and fruit."[74] That estimate is restricted to fungal pathogens alone–omitting viruses, bacteria, insects, worms, etc.–and omits animal losses. A quick examination of ten or so recent issues of the monthly journal of the US Agricultural Research Service of the US Department of Agriculture produced the following items:

- "California medfly battles have cost taxpayers nearly $500 million during the past 25 years. A 1997 attack on medfly in Florida's Tampa Bay region lasted 9 months and cost $25 million."[75] (This entry apparently does not record the cost of crop losses caused by the medfly infestations, only the costs of the eradication efforts, and this also seems to be the case for several of the items that follow.)

- "Marek's disease, a viral disease that causes tumors (in chickens). Before the first vaccine was developed in the late 1960s…the disease caused losses of $300 million a year…. Even with the vaccine, losses can still run as high as $100 million a year."[76]

- The Russian wheat aphid is a major pest of US winter wheat and barley, and the diamondback moth is a worldwide pest of cabbage, canola, and other cruciform crops. Each year farmers worldwide spend more than $1 billion to control diamondback moths.[77]
- "During 1971, a particularly nasty Newcastle strain...struck the poultry industry in California. Eradication took over 2 years and cost $56 million in federal funds."[78]
- "Brucellos...costs US beef and dairy producers nearly $30 million annually."[79]
- "The tomato spotted wilt virus...cost Georgia's peanut farmers $40 million in losses in 1997."[80]

Obviously, this brief and coincidental compendium is only meant to be indicative. Presumably the US Department of Agriculture and the UN Food and Agricultural Organization provide annual compilations of crop and domestic animal loss estimates for the US and globally, respectively. And of course the epidemic of FMD that broke out in England in February 2001, and which reached continental European countries by March 2001, will certainly register as a major example of a natural outbreak.

## References

1. The Breeders, a previously unknown group, sent letters to Los Angeles Mayor Tom Bradley, agricultural officials, and members of the media, including the *Fresno Bee*, in late 1989 claiming responsibility for spreading the Medfly through Southern California. The Breeders threatened to continue spreading the flies if aerial spraying of pesticides continued. Said one letter, "every time the copters go up to spray, we'll go into virgin territory or old Medfly problem areas and release a minimum of several thousand blue-eyed Medflies. We are organized, patient and determined." Scientists were unable to determine if the Breeders had spread the Medfly, but there were unusual aspects to the Medfly infestation. For example, fewer larvae were found than expected in an infestation so large, and adult flies were discovered just outside the spraying zones. Leon Spaugy, the county agricultural commissioner, is not sure if the adult flies were trapped or placed in the traps by someone. See: John Johnson, "Female Medfly Found in Sun Valley Close to Area Targeted Earlier," *Los Angeles Times* (4 January 1990), p. B3. Ashley Dunn, "Officials Advertise to Contact Mystery Group Claiming Medfly Releases," *Los Angeles Times* (10 February 1990), p. B3. Stephanie Chavez and Richard Simon, "Mystery Letter Puts a Strange Twist on Latest Medfly Crisis," *Los Angeles Times* (3 December 1988), p. B1 (Orange County Edition).

   One group that has been fighting a civil war in a South Asian country for approximately 20 years has threatened the use of anti-crop agents, but there is no known record of serious contemplation. I have also omitted any discussion of "product tampering."

2. Mark Wheelis, "Biological Sabotage in World War I," in E. Geissler and J.E. van Courtland Moon, eds., *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*, Stockholm International Peace Research Institution (SIPRI) Chemical & Biological Warfare Studies, No. 18 (Oxford, UK: Oxford University Press, 1999), pp. 35-62. See also Martin Hugh-Jones, "Wickham Steed and German Biological Warfare Research," *Intelligence and National Security*, 7:4 (1992), pp. 379-402; and Millet and Whitby, this volume.

3. M. Hugh-Jones, *op. cit*., pages 381-2; citing R.V. Jones, *Reflections On Intelligence* (London: Heinemann, 1989), p. 181.

4. Piers D. Millet and Simon Whitby, "State Agro-Biological Warfare Programs," this volume.

5. Olivier Lepick, "French Activities Related to Biological Warfare, 1919-1945," in Geissler and Moon, eds., *Biological and Toxin Weapons*, *op. cit*., pp. 70-90.

6. Maj. J.M. Barnes, *et al., A Review of German Activities in the Field of Biological Warfare* (ALSOS Mission) Intelligence Report, War Department, Washington, DC, September 12, 1945. The World War II German anti-plant program is discussed on pp. 99–106, and the anti-animal program on pp. 90–98. See also Erhard Geissler, "Biological Warfare Activities in Germany, 1923-1945," in Geissler and Moon, eds., *Biological and Toxin Weapons, op. cit*., pp. 91–126; John Hart, "The ALSOS Mission: A Case Study of Evaluation of Intent and its Relation to the Biological and Toxin Weapons Convention (BTWC) Protocol," VERTIC draft, March 8-9, 2001.

7. *Ibid.*

8. *Ibid*.

9. *Ibid*.

10. Sheldon H. Harris, *Factories of Death: Japanese Biological Warfare, 1932-45, and the American Coverup* (London: Routledge, 1994), pp. 84-99. See also P. Williams and D. Wallace, *Unit 731: Japan's Secret Biological Warfare in World War II* (New York: Free Press, 1989).

11. Sheldon Harris, "The Japanese Biological Warfare Program: An Overview," in Geissler and Moon, eds., *Biological and Toxin Weapons, op. cit*., pp. 139, 144.

12. P. Williams and D. Wallace, *Unit 731: Japan's Secret Biological Warfare in World War II* (New York: Free Press, 1989).

13. David Millward, "Allies Drew Up Plans to Poison German Crops," *The Electronic Telegraph* [*Daily Telegraph*, UK], January 8, 1996. It would appear from the British War Office documents released in 1996 and quoted in this press report that Whitby and Rogers's statement that "The US anti-crop biological warfare program emerged from domestic institutional arrangements that had been established during the late interwar years" is not correct. See Simon Whitby and Paul Rogers, "Anti-Crop Biological Warfare–Implications of the Iraqi and US Programs," *Defense Analysis* 13:3 (September 1997), pp. 303-318. In their Cornell conference paper, Millet and Whitby also state that the "British anti-animal programme … conducted during the Second World War … was instigated to counter the threat of German Foot and Mouth research." It is interesting that, as in the case of German "intelligence" regarding the BW programs of the US and UK in World War II, the information received from agents was frequently inaccurate, and at times so mistaken that its derivation is difficult to understand. That appears to be the case for "German Foot and Mouth research" as well; nor is there any indication that the British actually knew about what little German FMD work there actually was.

14. "Prime Minister: Bacteriological Warfare," *Most Secret*; Hankey, December 6, 1941. See also G.B. Carter, *Chemical and Biological Defence at Porton Down* (London, The Stationary Office, 2000), pp. 62–65.

15. John Bryden, *Deadly Allies* (McClelland and Stewart, Inc., 1989), pp. 46-49, 86-87, 94-103, 218–219, and 240-241.

16. *Ibid.*

17. Above all, Rexmond C. Cochrane, *Biological Warfare Research in the United States. Volume II of History of the Chemical Warfare Service in World War II (1 July 1940–15 August 1945)*, Historical Section, Office of Chief, Chemical Corps, November 1947, declassified.

    I am omitting reference to the several versions of the post-World War II Merck report (see below): the two books by Theodor Rosebury and the lengthy 1947 monograph in *Journal of*

*Immunology* by Theodor Rosebury and Elvin Kabat, as it is Cochrane's study that contains the most detailed description of the anti-animal and anti-plant portions of the World War II US program.

18. Barton J. Bernstein, "America's Biological Warfare Program in the Second World War," *Journal of Strategic Studies*, Vol. 11 (September 1988), pp. 292-317. See especially pp. 304, 308-310.

19. Hanson W. Baldwin, *Great Mistakes of the War* (New York: Collins, 1950). It is worth noting that until 1959, US military definitions included chemical herbicides as biological weapons.

20. George W. Merck *et al*., "Implications of Biological Warfare," Chapter 7 in *The International Control of Atomic Energy: Scientific Information Transmitted to the United Nations Atomic Energy Commission*, June 14, 1946–October 14, 1946, US Department of State, p. 7.

21. Personal communication to the author in 1969 or 1971, by Dr. Arthur Galston.

22. Dr. Eileen Choffnes, "Bugs, Biology and the BWC: The Environmental Legacy of Biological Weapons Testing," June 2000, manuscript.

23. J.P.P. Robinson, "Environmental Effects of Chemical and Biological Warfare," *War and Environment* (Stockholm: Environmental Study Council, 1981), Table 7.

24. Whitby and Rogers suggest that the remaining two, which were reportedly not produced in any significant quantity, may have been either late potato blight, rice seedling blight and brown-spot disease, powdery mildew of cereals, or bacterial soft rot. These guesses appear to build on assumptions of continuation of work done during World War II in the US program. Personal communication with the author by Dr. Simon Whitby and Piers Millett, November 2000.

25. 1967 memorandum on Project MkNAOMI, *Foreign and Military Intelligence*, Book I, Final Report of the Select Committee to Study Governmental Operations with Respect to Intelligence Activities, United States Senate, 94th Congress, 2nd Session, April 26, 1976, pp. 388-389.

26. Jonathan Ban, "Agricultural Biological Warfare, An Overview," *The Arena* [CBACI], No. 9 (June 2000): 2. Ban's footnotes for individual sentences are omitted here, but all but one came from the US Defense Intelligence Agency (DIA), *Chemical and Biological Warfare Capabilities–USSR*, March 1977, DST-16005-034-76-Sup. 1, pp. 236-245. The remaining item comes from the chapter by Valentin Bajtov and Ehrhard Geissler in Geissler and Moon, eds., *Biological and Toxin Weapons*, *op. cit.*

27. US Defense Intelligence Agency, *Chemical and Biological Warfare Capabilities*, *op. cit.*, p. 244.

28. Kenneth Alibek, "The Soviet Union's Anti-Agricultural Biological Weapons," in *Food and Agricultural Security. Annals of the New York Academy of Sciences*, Vol. 894 (1999), pp. 18-19.

29. Personal communication; however, there is also a brief reference to this in Ken Alibek with Stephen Handelman, *Biohazard* (New York: Random House, 1999).

30. Author's personal communication.

31. Anthony Rimington, "Anti-Livestock and Anti-Crop Offensive Biological Warfare Programs in Russia and the Newly Independent Republics," Center for Russian and East European Studies, University of Birmingham, June 1999.

32. Anthony Rimington, "Invisible Weapons of Mass Destruction: The Soviet Union's BW Program and its Implications for Contemporary Arms Control," *The Journal of Slavic Military Studies*. 13:3 (September 2000), pp. 1-46.

33. Judith Miller, "U.S. to Use Lab For More Study of Bioterrorism," *The New York Times*, September 22, 1999, p. A1.

34. This assessment is based on United Nations Special Commission (UNSCOM) reports and the author's interviews.

35. SIPRI, *The Problem of Chemical and Biological Warfare, Vol. 1: The Rise of CB Weapons* (Stockholm: Almqvist & Wiksell; New York: Humanities Press; London: Paul Elek, 1973), and SIPRI, *The Problem of Chemical and Biological Warfare*, Vol. II. *CB Weapons Today* (Stockholm: Almqvist & Wiksell; New York: Humanities Press; London: Paul Elek, 1973).

36. Jean Mayer, "Starvation as a Weapon: Herbicides in Vietnam I," pp. 115-121 and Arthur W. Galston, "Changing the Environment: Herbicides in Vietnam II," pp. 122-129, in "Chemical and Biological Warfare, A Special Issue," *Scientist and Citizen* 9:7 (September 1967).

37. Judith Miller and William Broad, "The Germ Warriors: A Special Report. Iranians, Bioweapons in Mind, Lure Needy Ex-Soviet Scientists," *New York Times*, December 8, 1998.

38. Judith Miller, "Flying Blind in a Dangerous World," *New York Times*, February 6, 2000.

39. Wendy Orent, "After Anthrax," *The American Prospect*, 11:12 (May 8, 2000).

    It also seems plausible that there has been some leakage of information to the Israeli BW program in more recent years.

40. See, for example, Jessica Stern, *The Ultimate Terrorists* (Cambridge: Harvard University Press, 1999), pp. 49-54.

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# Panel II:
# Technical Issues

# Technical Feasibility of Anti-Crop Terrorism

# 4

*William E. Fry*

Recognition that crops might be potential targets for terrorist activity is increasing, and some commentators suggest that US agriculture is particularly vulnerable. Anti-crop terrorism could take a number of forms, but the form most of us think of is probably that of crop destruction by some terrible organism (insect, weed, fungus, bacterium, virus, etc.). One can conjure fields of crops that are laid waste by some terrible biological warfare agent. Indeed, I have seen fields of crops that have been destroyed by plant pathogens. However, these epidemics were not caused by biological warfare agents, but rather by "naturally occurring" plant pathogens. Devastating crop loss caused by anti-crop terrorism is certainly within the realm of possibility, but there are many obstacles to successful implementation. These obstacles will be delineated in this paper. In addition to the crop-destruction model, other models of anti-crop terrorism (sabotage of crops or production systems) are possible.

This paper is presented from the perspective of a person who has investigated the many factors influencing epidemics of plant disease. Most of my efforts and those of my colleagues are directed at understanding epidemics of disease in crops so that eventually we will be able to mitigate the harmful effects of plant pathogens. In the course of these investigations, we often need to create epidemics under experimental conditions, and we have developed some experience in creating epidemics in the field. Additionally, some of my colleagues are interested in developing plant pathogens as specific weed-control agents, and some plant pathogens have been developed as bioherbicides with commercial implication. These colleagues are specifically interested in using plant pathogens to kill plants (weeds) and they have developed technology and knowledge that have apparent implications for biological warfare activities. In this paper I focus on uses of plant pathogens as anti-crop agents that have potential utility for terrorists. I will not address the use of insects or weeds as potential biological warfare agents. I should also add that I have no experience in developing plant pathogens as tools of biological warfare.

My thesis is that while devastating epidemics have destroyed crops at times during the course of human history, the manipulation of circumstances by a terrorist state or group to cause widespread crop destruction will be very difficult. Some circumstances are not readily influenced by human intervention. Even if such anti-crop activities are successfully initiated, there are effective responses now available that can mitigate the destructive potential. Thus, I will argue that widespread crop destruction has low probability of success. In contrast, crop sabotage might be much easier to achieve.

The paper is composed of several sections. First, I describe how a convergence of diverse factors is required for the occurrence of a devastating epidemic of crop disease. Second, in light of these generalities, I evaluate several historical occurrences of epidemics of crop disease. Third, I suggest that lessons might be learned from persons working on "biocontrol" of weeds. Finally, I suggest that crop sabotage is a more likely avenue for terrorist activity than is widespread crop destruction.

## Factors Required for Epidemics of Crop Disease

Severe crop disease is the exception rather than the rule. Most crops are not affected by most plant pathogens. Even for the small subset of organisms capable of causing disease in a particular crop, most crops are not severely afflicted by that disease in most situations. Often, disease is not serious and only a few plants are affected, or only a few leaves or stems are affected. However, there are exceptions when disease is very severe (with many plants affected severely). For this to happen, the crop needs to be susceptible to the particular strain of the pathogen and the weather needs to favor pathogen growth and development for a long enough time that the population of the pathogen can increase. Prior to the time that serious disease is detected, there will have been intervals during which the environmental conditions favored pathogen (and therefore disease) development. The dynamics vary according to the disease, but in some cases, episodes of favorable weather periodically over one or two weeks can lead to devastating disease. For other diseases, episodes of favorable weather over longer periods of time are necessary—months or, for some diseases, even years.

Widespread disease typically develops rapidly only for diseases in which the pathogen is dispersed effectively through the air. For diseases in which the pathogen is typically restricted to the soil, the development of widespread disease requires years. Most fungi, bacteria, and nematodes are sensitive to weather conditions. Viruses are less sensitive, but are sensitive to the occurrences of appropriate vectors. As we investigate several historical epidemics of crop diseases, the convergence of susceptible host crop, virulent pathogen, and favorable environment in a unique combination will be identified. However, even when these conditions are satisfied, there are now responses that can be implemented to prevent epidemics.

## Historical Epidemics

*Potato late blight and the Irish potato famine.* The Irish potato famine resulted when potato late blight (caused by *Phytophthora infestans*) destroyed most of the potato crop (plants in the field and tubers in storage) beginning in 1845 and subsequently. The pathogen was introduced to northern Europe just prior to summer 1845 and subsequently became an established component of the agro-ecosystem in Europe. Prior to 1845, the pathogen had been sequestered in the highlands of central Mexico, where it had co-evolved with wild relatives of the domestic potato. Domestic potatoes had come from the Andes of South America, so these two organisms had not co-evolved. The effect of the new disease in Ireland was to reduce the production of potatoes to ca. 30% of pre-1845 levels. Because potatoes contributed 80% of the calories for rural peasants, the crop shortage quickly led to famine. The combined effects of starvation and emigration reduced the population in Ireland from about 8.5 million in the early

1840s to about 6 million in the 1850s. The disease remained a terrible problem during most of the 19th century and became "controlled" only after the discovery and subsequent use of fungicides beginning in the late 19th century.

The Irish potato famine may epitomize the potential of anti-crop agro-terrorism; however, repetition of an event with such terrible consequences is highly unlikely. In the Irish potato famine, a plant pathogen was introduced to a new ecosystem, and near-total destruction of the vulnerable crop resulted. Several factors converged in that example that are now drastically different, so that a repeat of such disastrous consequences is highly unlikely. For example, the germ theory of disease was not yet established in 1845, so when the disease first appeared there was debate as to whether the organism associated with diseased potatoes was the "result" or cause of the disease. Ignorance concerning the cause of disease precluded the development of appropriate mitigation tactics. A series of appropriate tactics is now well established to mitigate the effects of plant disease in general and for potato late blight specifically. These now include the use of effective crop-protection medicines and the more rare use of "resistant" varieties. In 1845, intercontinental transportation was slow and arduous so that there were still examples such as this one, in which devastating pathogens were still isolated from vulnerable crops. Intercontinental transport of people and agricultural products during the subsequent 150 years has provided much opportunity for most such pathogens to contact susceptible host plants, so that this disease is now a problem wherever potatoes are grown.

However, introductions of exotic plant pathogens are still possible, and my experience with this same plant disease during the past ten years provides an example. Since the mid-19th century this disease had been particularly troublesome, with a very impressive crop destruction potential. In this regard, it was similar to many other plant diseases that could destroy crops. When the weather was particularly favorable for disease, severe disease could result, and rigorous efforts to prevent disease had to be implemented. These efforts were expensive at the least, and often not completely effective. If someone had asked me 15 years ago if new introductions of *Phytophthora infestans* would be particularly serious, I would have suggested that the effects would be only modestly or perhaps imperceptibly worse. However, my predictions would have been erroneous and my subsequent experience has made me more fearful of crop destruction by exotic pathogens.

During the latter part of the 20th century, strains of *P. infestans* were transported with agricultural products from Mexico to Europe and to the United States. These strains have worsened the late blight problem in all locations in which they have been introduced. The current problems are more serious than I would have predicted. The impact has been primarily on growers—creating economic and psychological hardship. There are several contributing factors. The new strains are more "virulent" or "aggressive" in that they cause severe disease more quickly. They have brought new pathogenic potential such that additional crops are now susceptible. They are resistant to a fungicide that had been particularly effective. They now have additional survival mechanisms such as the production of long-lived oospores. These characteristics evolved naturally over eons in Mexico, but in the context of agro-terrorism, could they be "developed" by a rogue state or group? Or could a rogue state or group "find" such strains? My initial response is that intentional development of such strains would be extremely difficult and unlikely, but clearly not totally impossible. Some scientists have attempted to develop strains of pathogens that have enhanced virulence, but this task has been frustrated by technical difficulties. I am currently unaware of instances in which highly pathogenic strains that can survive in the field have been developed. Similarly, I'm unaware of the development of strains that are not restricted by weather factors.

Despite the widespread occurrence of exotic strains of *P. infestans* throughout the USA and Canada, late blight is still a rare disease; and when the weather is not particularly favorable to growth of the pathogen, the disease is absent. Several years have passed since the introduction of exotic strains, and even when my colleagues have tried diligently to establish late blight in research plots, they have failed. For example, in 1995 the weather in the northeastern USA was very hot and dry and late blight was essentially not a problem anywhere in the northeast. Several of my colleagues could not initiate disease in their experimental field trials even though they inoculated the plots several times. In contrast, in 1994 late blight was widespread and very severe in the northeastern USA, because that summer was rainy and cool and virulent strains were present. Weather conditions were not limiting to the pathogen and successful aerial dispersal of the pathogen occurred frequently. These requirements for widespread and severe disease outbreaks have implications for the use of plant pathogens to destroy crops: even when the target crop is susceptible and the pathogen is particularly virulent, weather has a controlling influence. If the weather does not favor pathogen development, disease will not be a problem. It is hard for me to visualize circumstances that would enable a rogue state or terrorist group to develop a pathogen so virulent that weather would not be a controlling factor.

*The Southern Corn Leaf Blight epidemic of 1970*. This disease was probably the most serious plant disease to affect the United States in the last half of the 20$^{th}$ century. The disease affected corn in the corn belt and throughout the eastern half of the country. Total corn production was reduced by at least 10%, and this had a significant effect on prices. Analysis of the factors contributing to the epidemic might be instructive for our purposes in evaluating anti-crop agro-terrorism. In 1970, the vast majority of corn grown in the United States had the same cytoplasm (Texas male sterile cytoplasm = T-cytoplasm) because it was particularly useful in the production of hybrid seed. It turned out that mitochondria in T-cytoplasm had a defect that caused them to be vulnerable to a metabolite produced by a rare strain of a fungal plant pathogen. The metabolite caused the mitochondria to become leaky, and this enabled this strain (Race T) of the pathogen to grow rampantly in the tissue. The defect in T-cytoplasm corn went undetected during the initial testing of the cytoplasm because Race T was either not present in the United States or present at an extremely low incidence. However, during the summer of 1970, the disease caused by Race T affected corn throughout the corn belt (wherever corn with T-cytoplasm corn was grown) and created serious concern about the corn crop. The disease was serious because the corn industry had created a nearly uniform population of especially vulnerable crops. In general, weather conditions in the corn belt during that summer were favorable to disease development. The problem was limited primarily to a single season because the cause of the problem was quickly realized, and there was rapid movement away from hybrids with T-cytoplasm.

In the context of anti-crop agro-terrorism, we need to ask if any of our major crops have similar uniform vulnerability to some exotic pathogen? The exact mechanism of vulnerability is probably not predictable *a priori*, but the forms of uniformity might be predictable. For example, a small number of transgenes for resistance to insects or resistance to herbicides are present in high frequency in crops such as soybeans and corn. If there were some trait associated with these transgenes that could be exploited negatively in some as-yet-unidentified manner, then terrorists could perhaps employ this approach. However, at present, no such negative trait is known.

*Sorghum ergot in 1997-2000.* The introduction of sorghum ergot in the late 1990s had a very different effect than did the introduction of exotic strains of the potato late blight pathogen or the introduction of Race T of the southern corn leaf blight pathogen. The sorghum ergot situation might better represent the norm. This pathogen had not been reported in the Americas until the mid-1990s, but it had been a problem in India and Africa since the early 20$^{th}$ century. Dramatically, in 1995 it moved rapidly into South America and through Central America. By 1997, the pathogen had moved into Mexico and the United States. It was potentially a serious threat to hybrid sorghum production because the inbreds used in producing hybrid sorghum are much more susceptible than the resulting hybrids. However, sorghum ergot has not become a serious problem because again the weather has not been sufficiently favorable to enable rampant pathogen growth.

The sorghum ergot example again illustrates that widespread and severe crop destruction requires the convergence of many factors that are difficult to manipulate, and this poses an obstacle to anyone wanting to initiate disease—even terrorists. For the susceptible crop to be a significant target, it has to be planted on a wide scale. The particularly virulent pathogen has to be wherever the crop is growing. The weather has to favor pathogen growth. While these conditions might be met on local scales (e.g., tens of square miles), it is extremely difficult to achieve this convergence on the scale of hundreds or thousands of square miles.

*Lessons from weed biocontrol efforts*. There is a cadre of investigators who specifically attempt to use plant pathogens to kill weeds in agriculture. Their expertise is probably most appropriate to evaluate the vulnerability of US crops to anti-crop terrorism. There are two extremes in using plant pests to kill weeds. The classical approach is to identify an appropriate pest in some exotic ecosystem and then release it into the ecosystem containing the weed and hope that its natural development suppresses weed development. There are so few successful examples of this approach, and their application is so restricted in area, that the chances of success over a large area are vanishingly low. The more successful approach is to use plant pests (in most cases, fungal plant pathogens) as mycoherbicides (formulations of the fungus that are applied directly to the weed, much as a chemical herbicide is applied). Only very small numbers of such mycoherbicides have been developed. A serious constraint is that their successful use is often highly restricted to specialized agro-ecosystems (e.g., one successful agent is used only in rice paddies). Each field needs to be treated, sometimes repeatedly. This indicates that large amounts of the agent would have to be prepared and delivered directly to the target.

## Sabotage as a Terrorist Approach

Because widespread anti-crop destruction via biological warfare is technically very difficult, the use of anti-crop sabotage offers perhaps a more tractable approach. The goals would be different—creation of localized economic stress and perhaps confusion against a limited target, instead of mass destruction directed against large numbers of civilians. Ban (2000) suggested that the "planting" of a quarantined organism in the region of quarantine might achieve some of the goals of some terrorist groups. For example, consider the impact of the detection of a smut fungus (wheat pathogen) in Arizona in 1996. (This situation is offered only to illustrate the potential impact; there is no evidence that this situation is anything other than a natural event.) The fungus (*Tilletia indica*) was one against which the US had a quarantine. It had not before been detected in the US, and the US would not permit the importation of wheat from a country in which this pathogen occurred. Other countries had similar types of quarantines. Thus, when *Tilletia indica* was detected in Arizona in March of 1996, the $5 billion wheat export market was jeopardized. Individual wheat growers in Arizona immediately lost their export market. There was an immediate response by the US Department of Agriculture (USDA) to determine the extent of the occurrence of this fungus, and then to eradicate it. There was immediate confusion and concern, and millions of dollars were expended to deal with the incident. Wheat exports were in limbo for some months. Detection and eradication efforts were implemented immediately. Eventually, foreign markets accepted most exports and eventually the eradication efforts were successful. However, the cost of the response is estimated to be in the range of tens to hundreds of millions of dollars.

While there is every reason to believe that the occurrence of *Tilletia indica* in the United States resulted from natural causes (the fungus occurs in Mexico and is aerially dispersed), it would have been relatively easy to "plant" this pathogen in the United States. The spores of the fungus are microscopic and relatively long-lived. In this case, the pathogen does not have to cause disease; it needs only to exist and be found in the area. Here survival is important, and the teliospores of *T. indica* can survive in soil for quite some time. It would be easy to carry millions in an envelope or coin purse across almost any border. These could then be distributed to wheat in the field. Within several years, the fungus would have increased sufficiently in the population to be detectable; when the incidence is low, one has to look hard. This pathogen was probably in the USA for years before it was detected. *Tilletia indica* is not a devastating pathogen and rarely causes detectable yield loss, but when present in high numbers it can cause a "fishy" aroma in contaminated wheat. The major threat it posed to US agriculture was that it was "quarantined" and we and many other countries had stipulated that we would not allow imports of wheat from countries known to harbor this pathogen. Thus, the impact was exclusively economic. There are other pathogens that we attempt to exclude, and detection of them in the United States would create similar economic hardship generally, with specific hardship on affected growers.

## Conclusions

While there are many examples of terrible crop destructions by plant pests, the manipulation of these agents as biological warfare agents to destroy crops on a wide scale by terrorist states or groups faces severe technical challenges. The examples considered in this paper were limited to plant pathogens. Even if an aggressive plant pathogen can be developed or found, its potential is severely limited by meteorological conditions. Thus, it is difficult to conceive that a biological warfare agent could be used "at will" by a terrorist group or even by a state. The current availability of scientific expertise and plant-protection technologies would enable the agricultural community to respond quickly and mitigate the effect of a new occurrence of disease. Responses by the scientific and producer communities to new threats have been rapid in the past, and the maintenance of that expertise should enable rapid successful responses to future threats. In contrast to the technical difficulties that limit the success of massive crop destruction, it seems that introductions of quarantined pathogens might be relatively easy and could create confusion, annoyance, and economic hardship to limited segments of the agricultural enterprise.

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# Panel III
# Policy Responses

# Covert Biological Weapons Attacks Against Agricultural Targets:

## Assessing the Impact Against US Agriculture

*Jason Pate and*
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5

## Introduction

Since 1995, US analysts, policymakers, and the news media have focused unprecedented attention on the threat of terrorism involving weapons of mass destruction (WMD), particularly chemical and biological weapons (CBW). The Aum Shinrikyo attack in Tokyo in March 1995 and the Oklahoma City bombing the following month significantly contributed to this phenomenon in two important ways. First, Aum proved that subnational groups could obtain CBW, previously only a theoretical possibility.[1] After the Tokyo incident, terrorists using CBW appeared to be an evolving and dangerous threat that required creative new thinking in counter- and anti-terrorism policy. Second, the Oklahoma City bombing brought the threat of terrorism to the American heartland. No longer was terrorism a foreign phenomenon characterized by media accounts of masked Islamic fundamentalists taking hostages, hijacking planes, or bombing faraway buildings. The terrorists in this case were Americans targeting Americans: not only had terrorism reached the center of the country, but the terrorist threat originated much closer to home.

In an effort to address this "new" terrorist threat, the United States has tripled spending for CBW counterterrorist programs since 1995. A federal total of more than $1.5 billion was requested for this purpose in FY 2001.[2] Threat analyses have focused on the vulnerability of American society to attacks involving CBW, as well as the spread of the technologies and know-how associated with such weapons in the current information era.  Similarly, many government programs designed to address the CBW terrorist threat reflect this approach. In 1996, Congress passed the Defense Against Weapons of Mass Destruction Act (the Nunn-Lugar-Domenici Domestic Preparedness Program) in an effort to make the United States better prepared to respond to an attack involving CBW. This effort has been characterized by scenario development and training of the first-responder community, under the assumption that an attack would affect primarily civilians in urban areas.

More recently, the threat of a biological attack against an agricultural target, often labeled "agricultural bioterrorism," has been discussed.  However, programs to ensure preparedness for such an attack remain largely the purview of a limited part of the

US Department of Agriculture (USDA), which has begun to improve its capabilities to respond in the event of disease in animals or crops.[3] In an effort to address the potential threat of attacks against agricultural targets, USDA has developed a six-point strategy to ensure the security of US agriculture to include: (1) terrorism prevention and deterrence, (2) international cooperation, (3) domestic consequence-management planning, (4) research on counterterrorism capabilities, (5) protection of critical infrastructure, and (6) protection of the food supply.[4] This wide-ranging and somewhat vague list resembles many other federal agency counterterrorism plans. Interagency groups have proliferated with several other US agencies besides USDA now having some role in preparedness for agricultural terrorism, including the National Security Council and the Department of Justice.[5] This is also characteristic of US CBW counterterrorism planning in recent years.

The USDA requested a total of $41.3 million for counterterrorism in fiscal year (FY) 2001, $39.8 million of which (or 96 percent) is devoted to defense against WMD.[6] This is up from FY 2000, when WMD defense accounted for $7.3 million of $12.3 million, or 59 percent of the total.[7] Clearly, USDA has focused significant resources on addressing this problem. For comparison, the Department of Health and Human Services (HHS), the agency responsible for public health, including the Centers for Disease Control and Prevention (CDC), requested $265.4 million for counterterrorism activities for FY 2001, all of which was WMD-related, representing a decrease in funding from $277.6 in FY 2000.[8] The HHS FY 1999 request was $173.1 million, compared to $15.9 million in FY 1998, indicating either that HHS was able to capitalize sooner on the attention given the WMD threat or that the threat was perceived as more pressing in HHS's jurisdiction.[9]

The Department of Justice (DOJ) requested $254.7 million in WMD-related funding in FY 2001, an increase of $37.5 million over the previous year.[10] In the US national security community, funding for WMD-related programs has tripled since 1998, but the figures remain a small portion (less than 10 percent) of the total for general counterterrorism programs.[11] Other federal agency funding for WMD defense programs has also increased, but in no case has the proportion of WMD funding in the total counterterrorism budget been so great as in the case of USDA. This is most likely because the Domestic Preparedness Program until very recently has focused on preventing and mitigating attacks targeted directly at humans. The heightened focus on terrorism against agriculture represents a new stage, one with the object of protecting US infrastructure, such as agriculture. That said, USDA's funding levels, seen as a proportion of the US budget, trail those of other agencies dramatically in WMD-related appropriations. For example, the USDA's budget for this purpose is less than one-sixth of HHS's ($41.3 million compared to $265.4 million).[12]

Moreover, USDA has requested additional funding to upgrade an animal disease research facility at Plum Island, New York, to Biosafety Level 4. Local public opinion and congressional representatives have mixed views on the issue.[13] Building on these indicators of growing official attention to the threat of attacks against agricultural targets, including congressional hearings, news articles have begun to reflect concerns that US agriculture is vulnerable to attack using biological weapons. Arguably this vulnerability, as well as the theoretical ease of carrying out such attacks covertly, may make agricultural targets particularly appealing to certain terrorists.[14] Some terrorists may find these types of targets appealing because they do not target humans directly and may therefore be more easily justified. Indeed, a recent influential US government report asserted that the "US agricultural sector is especially vulnerable to agroterrorism" and that "a successful attack could result in local or regional economic destabilization" and affect international commerce.[15] The US agricultural sector, including all elements directly or indirectly related to agriculture, is enormous and diverse, representing about 13 percent of the US gross national product. In spite of its importance in the US economy, few specific threat assessments of vulnerability within the agricultural sector exist.[16]

It would be extremely difficult, however, for a terrorist group to perpetrate a significant biological attack against the agricultural economy in the United States for several reasons. First, obtaining and effectively delivering a biological agent against an agricultural target is a task fraught with technical hurdles. Although some agricultural agents can be obtained relatively easily and delivered crudely, a catastrophic incident would require a more sophisticated approach. Second, because crops and livestock in the United States are generally not concentrated together, eliminating a significant segment of the agricultural economy would require a multipronged attack and a sophisticated understanding of the economy. Although not impossible, this type of attack presents significant obstacles. Third, the US agricultural economy has in place networks and plans to respond to an attack once it is detected, and surveillance of crop and animal disease in the United States is extraordinarily sophisticated. Even if a terrorist group managed to deliver a biological agent effectively against a target, the effects of the attack would likely be severely limited by the US response. Fourth, although a determined group could conceivably carry out a devastating attack, there is no evidence of terrorist groups with the motivation to carry out a catastrophic attack against US agriculture. It is clear, however, that more research is required before an accurate assessment can be made of the threat that terrorism poses to the US agricultural economy.

The purpose of this paper is to assess what economic impact an attack using biological weapons would have on the US agricultural sector. There have been very few instances of what could be deemed "agricultural bioterrorism" in the United States; the empirical data are therefore quite limited. Although there have been some well-known cases of agricultural product contamination, these cases targeted people more directly rather than the crops or livestock themselves and were thus not examples of subnational actors seeking to eliminate a specific crop or portion of the agricultural base. Without a set of cases to examine, it is extremely difficult to predict accurately what an incident of agricultural terrorism would involve, how it would present itself, how it would be detected, and what its consequences would be. By looking at natural outbreaks of disease in segments of the agricultural economy in the United States, however, it may be possible to identify and quantify the actual impact of an attack against US agriculture. Although these outbreaks do not carry with them the same level of psychological impact that is normally associated with terrorism, they do provide a baseline for economic analysis and estimates of disease impacts on local, regional, and national economies.

This paper discusses definitions of agricultural bioterrorism and talks about some theoretical reasons why US agriculture may not be particularly vulnerable to an attack. The ideas proposed along these lines are similar to those in theories about the difficulty of perpetrating an effective attack using CBW against any target. After taking a look at the historical record of agricultural terrorism cases and making some observations, the paper reviews a number of naturally occurring outbreaks to provide a basis for determining the impact that disease in the agricultural sector might have. To assess the vulnerability of the vast US agricultural economy to terrorist attacks using biological weapons (BW), the paper then analyzes the diversity of US agriculture and comments on the feasibility of attacking regionally focused crops. Finally, the paper draws some conclusions from the data.

## Definitions

Before looking to natural outbreaks in an effort to understand what economic impact a subnational BW attack against an agricultural target would have, it is necessary and important to define the term "agricultural bioterrorism." One key issue in arriving at such a definition is how to categorize covert BW attacks. Are all such attacks terrorism? In some cases, where there is a terrorist group or individual using BW against agriculture, the term "agricultural bioterrorism" would obviously apply. In others, the motivations for the attack are criminal in nature with no link to furtherance of an ideological goal. Even in such cases, the attack is likely to have a psychological impact that goes beyond the immediate effects of the attack—a subsequent terrorizing effect. For this reason, these cases are covered in the analysis presented here even though they cannot by any reasonable definition be included as terrorism *per se*.

In this paper, we are speaking of subnational attacks against agriculture. To provide as comprehensive an analysis as the data allow, we use the term subnational BW attacks against agriculture to include all of these cases. Though this term is cumbersome, it allows for more accurate analysis. One could argue that attacks using chemical or even conventional weapons against agricultural targets could be considered examples of subnational BW agricultural attacks. For the purposes of this study, however, subnational BW agricultural attacks refer to the use of disease against agricultural targets, including crops and livestock, in an effort to cause widespread damage to or destruction of the target. This is a separate issue from the use of agents to contaminate specific products; in those cases, the target is actually people, and the incidents look more like consumer-product tampering. However, because of the paucity of incidents of actual agricultural terrorism, this paper provides an overview of product-contamination cases for context. Because chemical destruction is by nature self-limiting, we have chosen to look specifically in this paper at disease, with attacks using a biological agent.

Although often-cited cases of subnational BW agricultural attacks have involved threats of contamination of specific products, causing significant economic losses through diminished consumer confidence, they did not threaten the loss of an entire segment of the agricultural sector. Although the diffusion, both geographically and typologically, of agricultural production across the United States makes a catastrophic attack on or the total elimination of a significant portion of the national agricultural economy highly unlikely, regional economies could be significantly affected. However, certain segments of the agricultural economy in the United States may be sufficiently concentrated or sufficiently unique that an attack against them could have major regional consequences.

## Costs

Although this paper deals overtly with the economics of subnational BW agricultural attacks, a range of costs, in the wider sense, would be associated with such an attack. If crops or livestock are destroyed, then obviously that has a financial impact on the grower or breeder. Depending on the scale of the attack, however, it might have an impact on consumers, both in confidence, in the case of product tampering, and in product prices. Clearly, if a particular crop is in short supply, or if it has to be imported from a more remote region, then the price of that crop will rise. An example of this phenomenon attributable to natural causes occurred 1999 when frost decimated the California orange crop, causing oranges to be shipped from Florida, resulting in a rise in orange prices. Such an occurrence also has a ripple effect: the increase in the price of oranges adversely affected the Florida juice industry even though the frost had hit California. The increased costs were passed to the consumers of orange juice and table oranges.

Equally, though, various individuals and businesses are likely to suffer as a result of the secondary impact of subnational BW agricultural attacks. For example, if a crop is decimated, agricultural workers are likely to be seriously affected unless they can find alternative employment. In January 1999, for example, unemployment in Tulare County, California, hit 20 percent, largely as a result of the area's spoiled orange crops. A range of industries may depend on certain crops or livestock: a terrorist attack on cattle affects not only the farmer, but also the livestock shippers, stockyards, slaughterhouses, distributors, and so on. The economic impact of an incident depends not only on the scale of an attack, but also on the crop or livestock that is targeted. Where there are substitute goods for those that have been targeted, the economic impact can be reduced. Equally, some livestock or crops have more elastic supply than others, so that output can readily be expanded to fill a gap in the market. For example, because pigs have large litters and reach maturity relatively quickly, the supply of hogs is much more flexible than that of cattle.

Apart from the loss of immediate revenue from a subnational BW agricultural attack, there is also the risk of long-term loss of market share. If distributors, wholesalers, and retailers find acceptable and affordable alternative sources of agricultural produce to replace those affected by the attack, they may not return to their original supplier, even after the crisis has passed. This might be not only a consequence of subnational BW agricultural attacks, but conceivably a motive for them as well. Competitors in a particular market could see these attacks as a means of increasing their market share at the expense of their rivals.

Obviously, a range of other potential costs might also be incurred as a result of a subnational BW agricultural attack. Crops or livestock might need to be replaced. The expense of doing so could be particularly heavy if breeding stocks have to be replaced to replenish supplies of produce. Depending on the agent used to attack agriculture, the affected area will likely need to be decontaminated. Additional costs may include not only "cleaning up" the agent, but also collecting and destroying infected crops or livestock. If a virulent and readily transmissible agent such as foot-and-mouth disease (FMD) or certain wind-borne plant pathogens are involved, the need for collection and destruction may extend beyond those livestock or crops already affected to those in the vicinity. This would include those that <u>might</u> be affected, given the need to establish a *cordon sanitaire* to control the spread of the disease.

Finally, agricultural terrorism may generate political costs. Some of these costs apply to any act of terrorism: the loss of confidence and credibility stemming from a government's inability to protect the country. Specifically, however, terrorism involving BW attacks on agricultural may also result in a heightened need for interagency cooperation, possibly at local, state, and national levels, and calls for increased action against further such attacks. Therefore, subnational BW agricultural attacks may involve a range of costs, both direct and indirect, overt and hidden. Therefore, when discussing the economic impact of such attacks, it is important to be clear what costs are being incurred and by whom.

## Incidents Involving Subnatural BW Agricultural Attacks

As of August 2, 2000, the Database of WMD Terrorism Incidents at the Center for

Nonproliferation Studies, Monterey Institute, held 21 incidents that might be classified as subnational BW agricultural attacks.[17] This represents only a small fraction (2.5 percent) of the total number (853) of incidents contained in the Database. Clearly, in spite the attention that the threat of agricultural terrorism is now receiving, historically, such attacks have been relatively rare occurrences. Moreover, although high-profile concern over the potential threat is a relatively new phenomenon and has centered in the United States, the historical record suggests that acts of agricultural bioterrorism have been perpetrated worldwide for decades. Of the 21 incidents of subnational CBW agricultural attacks in the Database, five occurred in the United States, but four occurred in Israel, and there have been incidents in Canada, China, Sri Lanka, the Philippines, Australia, Uganda, and Kenya, as well as throughout Europe. The earliest incident in the Database occurred in Kenya in 1952, when members of the Mau-Mau, an anti-colonialist group, inserted the latex of the African milk bush plant into cuts made in the skin of 33 steers, eight of which died.[18] Even within the United States, members of the Ku Klux Klan supposedly poisoned the water supply of cattle owned by a group of Black Muslims in Ashville, Alabama, in March 1970. A local veterinarian identified the poison as cyanide. The incident may have been part of a sustained campaign of intimidation by the Klan against the owners of the farm. The poison killed 30 cattle and sickened nine others.[19] Clearly, then, the threat of agricultural terrorism is neither new nor limited to the United States.

Agricultural attacks are not primarily a means of targeting people *per se*: it would be simply illogical to attempt to attack people by targeting agriculture. Subnational agricultural attacks are therefore predominantly a means of extortion, intimidation (as in the example of the alleged Ku Klux Klan attack described above), or economic punishment. Although their impact is primarily financial, agricultural attacks have obvious social consequences as well that may be used as a tactic for political as well as criminal purposes. In fact, of the 21 cases of subnational BW agricultural attacks in the Database, only five were classified as criminally motivated. This is partly a consequence of the Database's inclusion criteria, but it is nevertheless extremely significant that 16 incidents were classified as politically motivated; agricultural terrorism is a means of political as well as financial extortion.[20]

When people have been injured or even killed as a result of agricultural terrorism, it has generally been when the incident closely resembles consumer-product tampering. In 1978, the Arab Revolutionary Council used liquid mercury to poison citrus fruit exports from Israel to Europe. Israeli orange exports were reduced by 40 percent, and 12 people were injured when they ate contaminated oranges.[21] In this case, though, despite the injuries, the primary target of the attack was the Israeli economy. A more serious case was uncovered in May 2000 when inspectors from the Israeli Agricultural Development Authority discovered that Palestinians had been using counterfeit stamps on expired and salmonella-ridden eggs that were then sold throughout Israel. Although they had been operating the scheme for 18 months, it is unclear how many contaminated eggs were sold or how many people were sickened as a result. In September 1999, two Israelis died of salmonella as a result of eating contaminated eggs. According to Israeli news sources, there may have been "widespread food poisoning in the Israeli Defense Forces and among tourists" as a result of the Palestinians' actions.[22] Clearly, in this case, the intended impact was not only economic, but also disruption of the Israeli military and society, a direct and politically motivated attack on people. Palestinian groups, more than other terrorist organizations, appear to have used such attacks as one in a series of strategies. In each case, the actions of such Palestinian groups are examples of the product-tampering type of agricultural terrorism.

In 1974 in Genoa, Italy, the "Revolutionary Command" announced that it had "injected toxic substances into Israeli-produced grapefruit."[23] In 1979, the Arab Revolutionary Council threatened to contaminate a range of Israeli agricultural exports to Europe.[24] Later in April 1988, again in Italy, the Organization of Metropolitan Proletariat and Oppressed Peoples, acting in support of the Palestinian Intifada, claimed to have injected poison into Israeli grapefruit. Grapefruit contaminated with a nonharmful agent were discovered in Naples and Rome, and the Italian government then withdrew all Israeli grapefruit from sale.[25] Interestingly, Israeli individuals or groups have targeted Palestinian agriculture too, but such attacks have been directed against crops rather than exports. Therefore, they have had a more direct, although possibly less widespread, impact than that achieved by Palestinian undermining of consumer confidence in Israeli fruit. In October 1997, settlers from Gosh Etzion sprayed a chemical on grapevines in two Palestinian villages south of Bethlehem. The settlers supposedly destroyed hundreds of vines and up to 17,000 metric tons of grapes.[26] In June 2000, settlers from Efrat released sewer water onto Palestinian fields in Khaddar, near Bethlehem. Farmers estimated their losses at around $5,000.[27] Although the settlers were undoubtedly pursuing a campaign to drive Palestinian farmers from the land, it is unclear whether they sought to do so by poisoning crops with sewage or by simply flooding the fields with the water.

Elsewhere in the world, agriculture has been targeted for a range of political objectives. In 1977, Ugandan dissidents threatened to poison the country's coffee and tea crops in an effort to severely affect Ugandan foreign exchange, thus undermining the economy.[28] The Liberation Tigers of Tamil Eelam (LTTE) (Tamil Tigers) threatened to use biological weapons to attack Sri Lankan crops in the mid-1980s.[29] In January 1984, Pater Vivian Wardrop threatened to use FMD to attack livestock in Queensland, Australia, unless prison reforms were undertaken.[30] In none of these cases was there any indication that an attack had actually been perpetrated or that an anti-agriculture agent had been successfully acquired.

Furthermore, forms of subnational agricultural attacks have been used as a means of settling personal scores. In the mid-1990s, a farmer in China used rat poison to kill 12 of his neighbors' water buffalo, along with four of his neighbors, supposedly because they were better off than he.[31] In 1997, Brian W. "Skip" Lea, of Berlin, Wisconsin, used the fungicide folpet and the illegal pesticide chlordane to contaminate products manufactured by National By-Products, a supplier for Purina Mills animal feed that he regarded as a business competitor.[32]

A number of cases worldwide and the majority of cases in the United States reflect terrorist targeting of exports or products rather than field crops or livestock *per se*. In the 1980s, Hukbalahap (Huk) terrorists poisoned Dole pineapples in the Philippines that were meant for export. However, the contaminated pineapples were discovered and destroyed, before any harm was done.[33] In September 1997, an ex-Kurdistan Workers Party (PKK) member claimed that the group planned to target Turkish vegetable exports.[34] In July 1986, threats from the Azanian Peoples Liberation Front (APLF), an anti-apartheid group, were published in the Canadian press that South African fruit would be poisoned with a toxic chemical.[35] Although no poisoned fruit was discovered, two Canadian supermarket chains ceased sales of all South African fruit.[36] The South African fruit sales ceased because of the poisoning threat at the time with no clear indication from the two supermarkets when sales would resume.[37] In November 1994, "the David Group" sprayed graffiti on railcars containing grain in Thunder Bay, Canada. Subsequent tests gave no indication, however, that the grain itself had been contaminated.[38] Within the United States, exports have also been a target: in January 2000 an e-mail message spread to internet users that warned that Costa Rican bananas were contaminated with necrotizing fasciitis, a flesh-eating bacteria.[39] The e-mail message was signed "Manheim Research Institute Center for Disease Control Atlanta Georgia," which is a false organization according to the Centers for Disease Control and Prevention.[40] No basis was discovered for the threat, and it is doubtful whether it is possible, even theoretically, to contract the disease as a consequence of eating food.[41] Clearly, these cases were targeted at potential consumers of the product.

More interesting was the 1989 case of the Breeders, a previously unknown group that threatened to spread Medfly throughout California if aerial spraying of pesticides continued in the state. The Medfly infestation in California at that time was unusually large and had a number of characteristics that led investigators to conclude that a deliberate infestation was being conducted. No one was ever caught for promoting the spread of the Medfly, and it is difficult to assess the validity of this example.[42] The case had a number of noteworthy aspects, particularly in that the motivation for the action was environmentalism. Although causing economic damage seems the most likely political reason to perpetrate an act of agricultural terrorism, the Breeders case shows that some single-issue groups might be similarly interested in such a tactic. Protesters concerned with genetically modified foods, as well as environmentalists, seem plausible candidates to consider an act of agricultural terrorism or agro-sabotage. The Breeders may have used a biological means, Medfly, to attack crops in California. By contrast, most attacks have either been hoaxes or relied on chemical agents to attack agriculture. It is biological, not chemical weapons, however, that can potentially have the most widespread effects on agriculture.

Of the agents used or threatened in the incidents of subnational agricultural attacks contained in the Database, eight cases involved threats to poison or contaminate crops or agricultural products with unspecified agents. In none of these cases was an attack actually launched, and all eight were simple hoaxes, threats, or plots. Six incidents in the Database involved a specific chemical agent directed against agriculture, and each involved the use of the agent: mercury, cyanide, rat poison, pesticide, fungicide, and an unnamed chemical. None of these incidents could be classified as sophisticated or involving high-end, or warfare, agents. Of the biological incidents in the Database, there were threats to use FMD, necrotizing fasciitis, and an unnamed biological agent. Of these, the threat to use FMD was notable because the potential use of the disease on agriculture elicits considerable alarm and concern among US officials and agricultural experts. Of the biological agents actually used, one was simply sewer water, another was salmonella in eggs, another a plant toxin from the African milk bush, and the last Medfly (although given the uncertainties of the case, this final example has to be treated with caution). Of these, perhaps only the Breeders incident could be considered significant for this study, as it involved the use of a biological agent in a way that could credibly have had widespread impact on agriculture.

It is useful to examine the economic impact of these incidents of agricultural terrorism from the Database. In 12 cases, no costs could be identified beyond the cost of harassment from the threats. In four cases, the perpetrators were able to kill animals, and in two of these four, people were killed as well. In only five cases is it possible to attribute financial costs to the activities. In one case, 17,000 metric tons of grapes were destroyed. In another, 300 lb of feed were halted from distribution, but it is unclear whether Purina destroyed the feed or simply tested it for contamination. In a third, Palestinian farmers lost an estimated $5,000. In a fourth case, two supermarket chains in Canada stopped importing South African fruit, but reports gave no estimate of losses in currency. In the most significant case, Israeli orange exports were reduced by 40 percent, but again, reports gave no estimate of costs incurred. In two of the more significant cases, the incident looked more like product tampering than like an attack against agriculture. In the other cases, costs were extremely limited and minimal. The historical record therefore suggests that it is difficult to achieve significant damage against agricultural targets, with the possible exception of product tampering. However, even in tampering, the financial or other impact is limited.

## Naturally Occurring Outbreaks of Disease

One means of determining the costs associated with potential subnational BW agricultural attacks would be to examine the impact of naturally occurring outbreaks of disease. Historically, a range of catastrophic diseases has affected US livestock and crops. Clearly, though, the impact of a particular outbreak of a disease is dependent on a range of factors: the characteristics of the disease, where it occurs, and the measures taken to deal with it.

At the time of writing, a major outbreak of foot-and-mouth disease (FMD) is occurring in the United Kingdom and has apparently spread to France, the Netherlands, and Ireland. The viral infection, which has affected ungulates and cloven-hoofed animals such as cattle, pigs, and sheep, has resulted in widespread import bans on livestock dairy and meat products from European Union countries. The disease is extremely infectious and can be spread through either direct or indirect (e.g., by dirty straw or on human clothes) contact with an infected animal. The British outbreak originated in a single pig herd in northeast England, where animals ate swill containing infected meat imported illegally from East Asia (FMD is endemic in areas of Africa, the Middle East, and Asia). As the origin of the British outbreak shows, the FMD virus can survive processing, explaining the ban not only on live animals from affected countries, but also on many animal products.

Between February 20 and May 14, 2001, 1,595[43] separate cases of FMD were reported in Britain, and a much smaller number of possible cases had been reported in France, the Netherlands, and Ireland. Although the disease has a relatively low mortality rate, (around 5 percent of affected animals, mostly those that are young or old), it has a major economic impact. The meat- and milk-producing capacity of affected animals drastically declines, and there is an increased incidence of miscarriages in animals that have suffered the disease. Within Britain, compensation is available, so it is more economical for a farmer to slaughter the animal than to keep it. More importantly, though, recovered animals may still be viral carriers, presenting a continued threat of infection, increasing the incentive to kill such animals.[44]

Although vaccines are available to counter FMD, ideally these should be administered before an animal is exposed to the disease. This is complicated further as there are seven major strains of the disease and several subtypes, limiting the effective scope of a vaccination against all varieties of the disease. The “killed” vaccines offer protection for just six to nine months, so animals must be repeatedly immunized. More important still is the need to sell meat to countries free of FMD. Because a vaccinated animal cannot be distinguished from one that has had the disease, and because the vaccination does not prevent an animal from acting as a carrier, then these animals cannot be sold. Vaccination, therefore, is an expensive option, particularly in countries where the disease is not endemic, with severe trade implications. Consequently, the more common response has been to destroy every cloven-hoofed animal on affected farms. Britain has already slaughtered 2,657,000 animals and plans to slaughter 75,000 more;[45] European countries have also slaughtered thousands of animals that may have come into contact with British livestock.

As well as incurring import bans, the outbreak of FMD has restricted the movement of livestock within Britain. Markets have closed, and only a small number of animals from unaffected herds are being moved to slaughterhouses, under tightly controlled conditions. Because culled animals from affected herds must be burned, rather than sold for meat, the restricted number of animals being slaughtered for food has resulted in a shortage that has had to be satisfied by importing meat from outside the UK, at an increased cost to consumers.

As of May 14, 2001, it was still too early to estimate accurately the economic costs to farmers and the wider agricultural sector, beyond that it will be devastating to both. Even those farms that are unaffected stand to suffer huge losses because the disease compelled all livestock markets to be shut, so most farmers have had no income, only expenses, for the past two months. Moreover, the economic prospects for such farmers are grim: their animals are now mostly past the optimum time to ship them off to slaughter, and when the markets finally do open, the price of meat will plummet because every farmer is in the same situation and will flood the market. Moreover, while there will be compensation for farms where animals are slaughtered as a direct consequence of FMD (either through infection or prevention), the compensation for indirectly affected farms is less certain. Even the money for slaughtered animals is unlikely to be sufficient to return farms to pre-disease levels. The government money is based on stock valuation, rather than being compensation for lost income. Once the outbreak is over, the cost of new animals for replacing herds and flocks is expected to be very high because of the relative scarcity of breeding stock.

The FMD outbreak has had significant political implications: the British government felt obliged to postpone a national election, widely anticipated to be called for May, to June, along with local elections. The government's handling of the crisis has been a source of political debate, and the government department responsible for agriculture, the Ministry of Agriculture, Fisheries and Food (MAFF), is itself under pressure, being accused of bungling the prevention and control of the disease.

However, it is hard to suggest that the outbreak presents a strategic threat to the UK economy: agriculture and even the associated loss of tourism are not significant enough. Farming currently represents 0.9 percent of the UK gross domestic product (GDP) and employs 1.5 percent of the UK workforce. The FMD epidemic is likely to reduce the value of the agricultural sector still further, as some farmers decide that their compensation does not permit a return to the occupation that offered economically marginal returns, even before the outbreak. Perhaps the economically more significant impact of the disease will be on tourism. Although FMD only very rarely affects humans (when it presents itself, as flu-like symptoms), tourist bookings for holidays in the UK have been severely affected by the disease outbreak, partly because access to large sections of rural Britain was tightly controlled, deterring visitors. Misperceptions and concern about the zoonotic nature of FMD may also have discouraged tourism in Britain. A report by accountants PriceWaterhouseCoopers (PWC) on the cost of the outbreak suggested that although the cost to UK agriculture would be between £500 million and £1.6 billion, the total cost of the crisis for Britain in 2001 could be between £2.5 billion and £8 billion, or between 0.3 percent and 0.8 percent of GDP.[46] By the end of April, the Centre for

Economic and Business Research estimated that the epidemic would cost farmers £3.6 billion, and the British Tourist Authority estimated £2.5 billion of overseas tourist revenue will be lost by the end of the year.[47] Clearly, a major disease outbreak, such as FMD, has the potential to be catastrophic on an individual farm level, be significant to the agricultural sector, but may not be devastating to the economy as a whole. The same distinction could apply in the US. In 1999, the sector of the economy directly related to agriculture represented 1.3 percent of US GDP[48] and in 2000 employed 2.6 percent of the US workforce.[49]

In the Netherlands in 1997, five million pigs had to be slaughtered as a result of swine fever. Because the disease, though harmless to humans, is highly lethal to pigs and extremely contagious, entire herds with affected pigs had to be killed to contain its spread. Given the restrictions on the transportation and sale of pigs, necessary to control the disease spread, the Dutch government had to impose breeding bans, and 1.5-million piglets had to be slaughtered to relieve the pressure on overcrowded sties. The cost of compensation for the cull and cleanup of affected farms is estimated at $2 billion. Of this sum, the Dutch government contributed $900 million, and the European Union (EU) contributed $1.1 billion from the EU agricultural fund. Moreover, pig breeding usually contributes about $2.25 billion to Dutch exports; the disease knocked a half point off the country's GDP for the year.[50]

As another example, a 1999 dioxin contamination in Belgium cost Belgian food producers and farmers hundreds of millions of dollars. The incident arose from contaminated feed and led to bans of Belgian eggs and poultry, and also beef, pork, and some dairy products across the EU. It is believed that the original contamination was at Verkest, a company providing animal fats to animal feed manufacturers. The impact continued to spread: nine Belgian, one Dutch, and one French feed manufacturer were supplied with contaminated products, leading to bans on all EU chicken and pork in the United States, Japan, and Brazil. By September 1999, estimates of the cost of the incident to Belgian farmers varied—between $750 million and $1.5 billion—and the Belgian government estimated that it had cost the country around $900 million in lost tax revenue, chemical testing, and veterinary bills.[51] When FMD struck Taiwan in 1997, more than four-million pigs had to be slaughtered. Before the outbreak, the swine industry represented nearly 60 percent of Taiwan's livestock products. After the outbreak, pork prices collapsed, and it was estimated that damage to the Taiwanese economy might include $3 billion of lost sales, the jeopardizing of 50,000 jobs, and a half-point slowdown in the country's economic growth.[52]

Within the United States, the economic consequences of naturally occurring outbreaks have been less catastrophic than those overseas. In 1999, the Mexican fruit fly threatened agriculture across California, when it was discovered in San Diego County and Fallbrook County. The fly attacks more than 250 species of fruits, nuts, and vegetables, laying eggs in ripening fruit and thus spoiling it for sale and consumption. The agricultural economy in San Diego County alone is worth $1.2 billion, but it is difficult to determine the effects of subsequent bans on fruit exports from the county by the Australian, New Zealand, Taiwanese, and Japanese governments. Mediterranean fruit flies were discovered in Riverside County, and guava flies were found in Fresno County. According to the California Department of Food and Agriculture, the state's worldwide fruit exports were valued at about $2 billion in 1997; in 1997 combined fruit, nut, and vegetable production was almost 39-million tons, or more than half of total US production.[53] Within the state, 132,000 jobs and $13 billion depend directly or indirectly on fruit farming. However, thanks to a rigorous program of quarantine and eradication, the damage to California agriculture was a mere fraction of these figures.

In 1994, late blight, the fungal disease that caused the Irish potato famine in the 1840s, caused $100 million damage in the United States. The costs of attempting to suppress the late blight within the country equaled the direct losses. The majority of seed potatoes come from a single region, Europe, so the late blight developed into a worldwide problem, with outbreaks in the Middle East, South America, Asia, and Africa as well as Europe and North America. In 1997, the International Potato Center in Lima, Peru, estimated that losses worldwide from late blight were about $3 billion annually. In 1995, growers in Washington and Oregon alone lost $30 million. In 1994, a single New York grower lost $1 million, despite extensive use of pesticides, as marketable yields fell by 80 percent.

One of the means employed to control the worldwide spread of pathogens is export controls. The World Trade Organization (WTO) has "phytosanitary" rules that permit even a minor disease outbreak to compel the cessation of a crop's export. This can be seen in the cases of the fruit flies in California and karnal bunt in Arizona. In the latter example, a relatively mild but highly infectious pathogen was discovered in Arizona wheat. In one day, 32 countries banned US wheat imports. It cost the United States hundreds of millions of dollars to eradicate the fungal pest and threatened the country's $5 billion of annual wheat exports.[54]

Differentiating between naturally occurring outbreaks of disease and those caused purposefully by subnational entities is extremely difficult and may be impossible if no group or individual comes forward to claim responsibility for the outbreak. Epidemiological evidence may suggest the intentional spread of disease, such as the appearance of a strain of disease not endemic to the region, or the occurrence of the disease at several nonproximal sites simultaneously. Even this type of information, however, may not be completely reliable. The outbreak of West Nile virus in the northeastern United States that began in September 1999 is such an example, being a naturally occurring outbreak of an exotic, nonindigenous, disease, never previously seen in the United States.[55] In addition, if it were discovered that a particular outbreak was intentionally caused, would it be in the public's best interests to make that information widely available? Doing so could create panic and incidentally assist the goals of the perpetrator. Naturally occurring outbreaks continue to have economic impacts, but thus far, subnational attacks against agricultural targets have been limited in scope and sophistication. Technical obstacles to effective acquisition, maintenance, and delivery of microorganisms partially explain the limited scope of such attacks, but a more telling explanation is that there is little evidence that subnational groups are interested in this type of attack.

It is widely acknowledged that usable agricultural pathogens are likely to be more easily acquired than human pathogens. Dissemination of these agents may also be extremely straightforward, in some cases, such as that of some rusts or FMD, which supposedly require no more than swabbing an infected animal or crop and transferring the disease elsewhere. The theory holds that these highly infectious diseases would then spread naturally within their new host population. However, rigorous surveillance, quarantine, and eradication programs are likely to help curtail the spread of such diseases, and crop pathogens are generally vulnerable to environmental factors such as light, heat, and wind. Even with frequent transport of agricultural goods across the country, it is reasonable to hope that outbreaks initiated or spread by such methods might be contained within a region. In such circumstances, the attack need not be catastrophic. To achieve widespread effect in all but the most localized crops (such as almonds), multiple attacks would likely be necessary. Discussion of such an approach is beyond the scope of this paper, but it clearly increases the quantities of agent required and the likelihood of being apprehended.

## Diversity of US Agriculture

Part of the reason the United States has been able to avoid some of the most catastrophic consequences of agricultural pestilence has been the diversity of the national agricultural economy.[56] In 1997, the market value of agricultural products sold in the United States was more than $208 billion. Although some states clearly had disproportionate shares of the total, it was widely distributed across the United States. California was the leading agricultural state, with products valued at $25.2 billion, or 12.1 percent of the US total; Texas was second with $13.4 billion, followed by Iowa ($12.8 billion), Nebraska ($10 billion), and Illinois ($9 billion). The top five states accounted for 34 percent of the US total. However, 27 states, spread across the country, had agricultural products valued at more than $3 billion; 20 states had more than $4 billion of business; and 9 had $6 billion.

A similarly diverse geographical pattern can be seen among individual agricultural products, particularly major crops and livestock. Of the leading states, measured by cash receipts in 1997, Texas produced about 16 percent of US cattle and calves and about 22.5 percent of US cotton; California about 17.2 percent of US dairy products and 14.7 percent of the country's hay; Iowa about 18.5 percent of US corn, 22.4 percent of the country's hogs, and 17.9 percent of its soybeans; Georgia about 16.1 percent of US chickens; and Kansas about 16.8 percent of US wheat. Clearly, although there are some regional concentrations, such as cattle and corn in the Midwest, the scale of production and geographic distances involved offer some level of protection against catastrophic attacks.

Some other crops are far more concentrated and thus potentially more vulnerable to a major attack. Using 1997 US cash receipts figures, we find the following concentrations: 92.2 percent of grapes, 47 percent of tomatoes, 33.8 percent of oranges, 77.8 percent of lettuce, 100 percent of almonds, and 75.5 percent of strawberries were grown in California; 65.7 percent of oranges in Florida; 53.5 percent of apples in Washington; 43.3 percent of rice in Arkansas; 41.3 percent of tobacco in North Carolina; and 38.9 percent of peanuts in Georgia.

Even within individual states, crops may be further concentrated, making them even more vulnerable to attack. Three adjacent counties in California—Fresno, Madera, and Tulare—produced 55.1 percent of all US grapes in 1997. Another striking example is lettuce. California cultivated 77.8 percent of US lettuce in 1997. Within California, 57 percent of the national acreage for lettuce production was in the six bordering counties of Santa Cruz, Monterey, San Benito, Fresno, San Luis Obispo, and Santa Barbara. Strawberry production provides another impressive illustration. A little more than 41 percent of Californian strawberry production, which comprises more than 75 percent of total US production, was in two contiguous counties (Santa Cruz and Monterey), and another 33 percent of Californian production was in two nearby counties (Santa Barbara and Ventura).

In addition to these specific concentrations, it is important to note that a few counties spread over the San Joaquin Valley produce most of these crops. A disease that could affect several crops would have even greater impact on regional economies and aggregate production, thereby increasing the apparent vulnerability of certain sectors of the US agricultural economy.

However, this geographical diversity of agriculture can be slightly misleading. Although spread over several states, 70 percent of US beef cattle is raised in an area with a 200-mile radius. Moreover, the concentration of animals on individual farms can also magnify the impact of an attack. Large poultry farms may have hundreds of thousands of birds; dairy herds can have thousands of cattle. Some animals, such as pigs and poultry, are often raised intensively and in close quarters. In such cases, even where a disease does not compel that an entire farm be slaughtered, the spread of the disease in such confined conditions may be rapid and extensive. Intensive farming, using large-scale and automated feeding, also increases the scope for attacks that use animal feed as the means of delivery. By contaminating the feed on such a farm, an attacker could legitimately hope to reach a high proportion of the animals.[57]

A similar phenomenon is observable in arable farming in the United States. It is common practice even for large farms to focus on one or two crops, rather than grow a range of different ones. It is therefore entirely possible to threaten thousands of acres of farmland with a single pathogen, because all the fields are planted with the same crop. In such circumstances, even effective surveillance might be a challenge. On large farms, production methods such as spraying and harvesting are highly automated, so it might be weeks before a problem is observed. In the meantime, the pathogen may have been widely disseminated by the wind and by insect, bird, or animal vectors.[58] The danger is compounded by the dependence of US agriculture on a few regions for seeds. For example, the Idaho valley provides most of the US seeds. This greatly increases the opportunities for contaminating seeds and causing a "sleeper" outbreak of disease, capable of blighting crops across the United States.

In summary, the US agricultural sector, as a whole, appears to be sufficiently diverse and vast as to be invulnerable to a catastrophic subnational BW attack with a significant economic impact. That said, certain portions of the agricultural economy may nevertheless be concentrated or organized in such a way that a sophisticated attack could have significant economic consequences at the regional, state, or local level.

## Conclusions

Agriculture throughout the world, including within the United States, is extremely vulnerable to attack, in that such an attack would be relatively easy to perpetrate. However, achieving widespread impact from such an attack would be significantly more difficult. The historical record shows that there have been relatively few such attacks worldwide that have even sought catastrophic consequences. Rather than seeking to eradicate a crop or type of animal or poultry from a country's agricultural economy, most attackers have focused on damaging consumer confidence. This has meant that such attacks have been much closer to examples of product tampering than to the devastating strikes that have been the focus of a growing number of government reports, academic articles, and newspaper columns.

The economic impact of such attacks is, potentially, enormous. Within the United States, agriculture is an industry worth hundreds of billions of dollars and, directly or indirectly, employing millions. The willingness and ability of an attacker to jeopardize more than a fraction of that, however, appears limited. Moreover, the size of the United States and the range of agriculture within the country make it likely that even a major attack would be highly damaging rather than crippling to the country's economy. In addition, although the relative ease of releasing BW agents against agriculture, compared with that of BW agents against human targets, implies that BW attacks against agriculture could be quite effective, the potential ease of delivery may be offset by these limiting factors. Effective delivery would at the very least require a sophisticated, multi-pronged attack to achieve major effects, and be capable also of overcoming the environmental barriers to effective dissemination.

Historically, most worldwide attacks against agriculture have been directed at consumer confidence and could more legitimately be described as credible threats than as genuine attacks. The number of actions directed against agriculture *per se* has been limited, and none appears to have occurred on the scale presently being envisaged. However, relatively little is known or understood about the threat of subnational BW agricultural attacks. The potential vulnerability to attack could be enormous and could have economically disastrous impacts on individual farms and possibly on specific segments of the agricultural economy. It is important to point out, however, that the agricultural economy as a whole, as well as the entire US economy, are unlikely to be significantly affected. However, there is currently a gap between what has actually occurred in previous incidents and this perceived danger. Further research needs to be undertaken to ascertain whether there is a genuine danger and whether the terrorist threat has evolved to the point that terrorists now see agriculture as a worthwhile target. Alternatively, this perceived danger may simply be the latest example of vulnerability-driven, rather than intent-driven, threat assessments. In either case, it is important that more work be undertaken to ascertain the scope of the problem, and determine the best means of minimizing the danger.[59]

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# The Role of Disease Surveillance in the Watch for Agro-Terrorism or Economic Sabotage

6

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The potential for terrorist attacks and economic sabotage against agriculture in the United States has always existed, but only since 1998 has it officially and publicly been characterized as a "not if, but when" threat. While there are many possible reasons for the threat assessment, certain among them is the recognition that the vulnerability experienced in other sectors—terrorist bombings, a few instances of the intentional use of pathogens and chemicals against humans, and numerous recalls of bacterially contaminated food products—exists also in agriculture and food production. The early 2001 outbreak of foot and mouth disease (FMD) in English piggeries, after that country's 20-year FMD-free status, exponentially increased fears that protection derived from decades and billions of dollars spent in ridding the US of economically significant infectious animal diseases might be reversed overnight.

There is also a case to be made for the notion that bioterrorism—whether politically or economically motivated —is at this point in time a greater threat against US agriculture than it is against US citizens. There are several points in such an argument:

A. Using pathogens[2] and pests to attack animal and plant populations could introduce a new dimension to terrorist strategies. Although the history of biological weapons includes the production by several countries of anti-animal and anti-plant pathogens that could be used to sabotage food supplies and transport capabilities, in only one instance has use of such agents been confirmed in the past century. Glanders and anthrax were used by Germany in World War I to intentionally infect horses being shipped from the United States, Argentina, and Morocco to Europe. The presumption of military historians is that the agents played a role in the deaths of animals that did not complete the journeys, but to what extent is not known because necropsies were either not attempted or not recorded. Proven success of widespread damage from use of anti-agro agents would be a "first"[3] in contemporary history and, thus, perhaps constitute an appealing new weapon for a terrorist arsenal.

B. Intentional use of pathogens against animals and crops is less repugnant to prevailing sensibilities than their use against humans. Notwithstanding the fact that many countries, including the US, have in the past developed, produced, and stockpiled biological and toxin agents for possible military use, there has long existed in non-military circles a "norm" of repugnance against their use. This "norm" provided the foundation for the Geneva Convention of 1925 and the Biological and Toxins Weapons Convention (BTWC) of 1972. It also prompted President Richard Nixon in 1969 to order the destruction of the US stockpiles and to limit the US program to defensive research only. The "norm," however, is less compelling a protection for animals than for humans. As the canary was used to detect dangerous gases in mines, chickens are routinely used as sentinels for identifying the appearance of encephalitis viruses. As the US experience with West Nile virus has continued, deaths of crows, songbirds, horses, and small wild mammals are, without apparent concern, pointed to by public health officials as barometers of the potential for more human infection.

C. Use of animal and plant pathogens or pests cannot be easily proved to be intentional if no "exotic"[4] or "novel"[5] agent is used, and cannot be definitely proved, short of informants or eyewitness accounts, if an "endemic"[6] or "previously eradicated"[7] agent is used. There are numerous serious animal and plant disease pathogens, as well as crop pests endemic to the US. In most cases, their appearance is prevented and their damage is controlled. This is accomplished through vaccination, strict border inspection and quarantine regulations, sterile insect technology, germ plasma modification and breeding for resistant genotypes, judicious use of pesticides, preventative agricultural practices, and "good-sense" avoidance of exposure. There are also pathogens and pests that once caused disease and damage but were eliminated to the point that no cases or events have been identified for many years.

The downside of this fortunate situation is that the longer a disease or pest is not seen in a locale the larger the temptation is to relax the preventative measures. This is most aptly illustrated by the reappearance of whooping cough and measles in children whose parents were lulled by disease statistics into foregoing vaccination. With respect to animal and plant populations, occasional lapses in these measures bring the possibility of loss; continuing lapses bring the certainty of loss, as has been demonstrated in countries formerly part of the Soviet Union, where disease prevention has largely collapsed. In recent years, numerous plant diseases and crop pests have reappeared in the US. Citrus canker is a serious problem in Florida; Pierce's disease threatens grapes and avocados in California. Both situations involve diseases thought eradicated. There is absolutely no indication that they were intentionally re-introduced, but had they been, it would be extremely difficult to prove. It seems reasonable, therefore, that the clever saboteur might forego diseases not ever identified in the US and consider those that have been detected previously, as well as those that are endemic to the US or other countries in North America.

D. Certain agro-terrorist actions can be instigated without violating international arms-control agreements. The protocol now being negotiated to put some teeth into the BTWC includes language designed to act as blanket coverage of all hostile acts using biological or toxin agents. However, the definition of "hostile" is still in brackets (not yet adopted). The suggested definition is:

"Hostile purposes mean [Any purpose, which has no prophylactic, protective or other peaceful intention.]

[4 bis (a) The use of bacteriological (biological) or toxin weapons or the threat of use [by a State] with a view to inflicting military, economic, [moral] or other kind of damage; ....]"

Until "economic...or other kind of damage" escapes the bracketing and becomes a permanent provision of the protocol, and until the protocol is adopted and ratified by States Parties, there is no prohibition against agro-terrorism or economic sabotage, absent development, production, and stockpiling of prohibited agents. What is further disturbing about the bracketed language is that even though the protocol has been in negotiation for more than six years, there are still no definite parameters, no surety of what actions the protocol prohibits. At this juncture, the actions behind the hypothetical scenario described later in this paper would not constitute prohibited purposes.

E. Causing death or disease in animals, or damage to crops, is unlikely to incite either a crushing military response or an international manhunt beyond normal investigative procedures. The potential response of the US to hostile use of biological and toxin weapons against American agriculture is unknown, because it comes under the "intentionally vague" weapons of mass destruction (WMD) response policy adopted during the past decade. Much would depend on whether the saboteur is attached to known or suspected terrorist activity by a state or substate group, whether any group or individual claimed credit for the attack, whether a trail to anyone was established early in the investigation, and to what extent public outcry for action ensues or public support can be developed.

If these points in the argument, that attacks against agriculture are more likely than those against human populations, have merit, then those who predict agro-terrorism rather than human bioterrorism may be correct. Even if they are incorrect, US agriculture is a tempting target for the use of highly contagious disease agents that infect animals and result in wholesale slaughter or pests that infest crops and result in vast crop burns and/or disrupt food production and trade. Newcastle disease and highly infectious avian influenza can temporarily wipe out entire poultry operations. Foot and mouth disease (FMD), swine fevers, rinderpest, and the new Nipah virus can disrupt beef and hog production. Bovine tuberculosis can temporarily arrest milk supply and prejudice dairy products. The new Hendra virus (the equine morbillivirus that surfaced in Australia in 1994) and various equine encephalitis agents can be used with sufficient effect against horse-breeding operations.

In using biological agents against US agriculture, the goals of a terrorist or saboteur would not necessarily be to destroy whole animal populations, or even to empty the meat bins at supermarkets for any sustained period of time. Noneconomic goals might be far more subtle and, therefore, capable of insidiously undermining our society, political system, and economy. Some of those goals might be to:

- Make Americans aware of their vulnerabilities.
- Create skepticism that government can protect American interests.
- Build distrust in the national food supply.
- Incite anger at the particular administration in power.

Economic goals might be to:

- Disrupt America's sizeable international trade in agricultural products.
- Increase the perpetrating country's market share.
- Retaliate against import bans or pejorative marketing schemes.
- Stymie growth in prosperous times or deepen recessions.

It is thought by some analysts that much of the current rhetoric about agro-terrorism exists because there is a trend in the US Congress to address certain needs not on the popular agenda only if it can be convinced of their importance to national security. Thus, when the US Department of Agriculture (USDA) needs an additional argument for funding proper and necessary research at the Plum Island, NY, facility, or hiring more Animal and Plant Health Inspection Service (APHIS) inspectors or engaging in more cooperative work with other countries to find out what is going on outside US borders, the current winning argument is terrorism.

In any case, what we need to do to meet potential terrorist-type threats is the same thing we need to do to ensure the continuity of a safe and ample food supply, to protect our international markets, to avoid the high costs involved in stamping out a disease that should not be here in the first place, and to enhance our scientific and political credibility. One essential element in a plan—either to be prepared for these threats or to take care of business as usual—is proactive and inclusive disease surveillance.

The observations of the animal owner or farm manager, the general impressions of a herd or flock noted by a veterinarian or agriculture extension officer, or examinations or tests of individual animals when disease is suspected or evident are basic to surveillance, as are the records of the above activities and subsequent reports to authorities. However, with the US system of notifiable diseases, information in some cases may be set aside. If the diagnostic test indicates a disease not on the notification list, or if it is inconclusive in a situation where the problem is confined to a few small farms, a kind of hit-and-run scenario, the information may not be preserved in an easily accessible format or may even be discarded altogether. Thus, at the state and national level, this element of surveillance may more accurately be thought of as monitoring, because it takes the form of a compilation of basic information on notifiable diseases—which notifiable disease, how determined, and where and when.

Further, there can be disconnect points along the information path towards the compilation. If the owner or farm manager does not call in a veterinarian or extension officer, no information will be generated. If the extension officer or private veterinarian, perhaps as a favor to his client, makes no report to state authorities, or if the laboratory, perhaps as a favor to the veterinarian, makes no report, the compilation is incomplete.

While monitoring *records* prescribed information, surveillance *creates* a body of data that describes all significant factors in disease outbreaks—data that may allow us to know how and why the disease has occurred and if the disease is changing, spreading into new areas, or infecting new species—data that may suggest ways to prevent future occurrences. Moreover, surveillance in its most productive form will not be limited to a short list of notifiable or most feared diseases.

When some people talk about disease surveillance, they often appear to be talking only about passive activities—receiving information generated by others and processing it through computers to store and sort and model into something to look at. While this is obviously an important function, it is much like gauging the size of an iceberg by looking at its tip from a far distance.

Surveillance, in contrast, is an active process that measures the total mass of the iceberg. To stretch the analogy a bit, it explores the water around it, the air above it, the ice mass it broke away from, the rate of its melt, the direction it moves and at what speed, and its relationship to other icebergs in the same area or to icebergs concurrently existing elsewhere. As applied to outbreaks of animal disease, surveillance measures both the actualities and the possibilities existing in individual herds and flocks, in breeding operations, in feed lots, in imports, in vaccination programs, in feed stuffs, in climate anomalies, in transport, and even in the disposal of aborted fetuses and manure. It takes time, it takes talent, it takes money, and it takes enormous prescience to know where to deploy those resources to best advantage.

How is surveillance achieved beyond the passive stage? There are at least four generic categories of activity in our current approach, and all of them are investigative in nature.

- Port-of-entry import inspection and quarantine.
- Immigration screening and fumigation.
- Extension services and field investigations.
- Diagnostics and research.

A. Port-of-entry import inspection and quarantine: The US has a system, APHIS, that has been highly effective for many years. Information in the public domain indicates that failures to detect pests and to quarantine for pathogen possibility have been few and far between, and none devastating. What are some of the pressures that could alter that record?

- Changes in, and additions to, the list of trading partners resulting from globalization.
- Increased importation of relevant commodities.
- Cuts in funding or failure to increase funding to cover heavier workloads.
- Inability to attract and train qualified inspectors.
- Political and trade pressures (local or international).
- Lack of timely response to international events.
- Failure to apply or to develop appropriate screening diagnostics.

B. Immigration screening and fumigation: While the US system for barring the entry of suspect or illegal aliens and for detecting customs violations is developed to a high degree of efficiency and effectiveness, its ability to prevent the introduction of pests, disease vectors, and pathogens into the country by travelers is just short of abysmal, as is true for a number of other countries. What are some of the obvious deficiencies?

- No requirement that returning US citizens specify where travel took them, type of area (urban, suburban, rural, park/sanctuary/reserve) and specific reason for travel (business, professional, conference, education, vacation, personal).
- Insufficient and provincially oriented questioning ("Did you visit a farm or ranch?").
- No requirement that US citizens specify their employment or profession.
- Profiling of certain foreign visitors (e.g., those who are not required to have a visa for entry) as nonrisks and treating them as casually as US citizens.
- No routine fumigation of planes, cruise ships, or vehicles upon arrival from countries where infectious disease vectors are prevalent.

The pivotal questions are: Is there sufficient interest in curing these deficiencies? Should new approaches be applied in an *ad hoc* manner, *i.e.*, when there are major outbreaks in progress around the world, or should new approaches be applied routinely? If applied routinely, should new approaches be phased in gradually? Will new approaches actually cure the deficiencies, or increase resistance to current measures?

C. Extension services and field investigations: Extension services are usually provided by state universities in cooperation with state and federal departments of agriculture. It is difficult to characterize their operations with respect to disease surveillance and clinical services, because each state cooperative extension service focuses on the needs of the majority of in-state farmers. In states where livestock and poultry production is preeminent, animal-production programs are likely to be more extensive than crop disease and pest programs. Extension services traditionally include farmer education and hands-on assistance.

Field investigations are largely formed and carried out by state agriculture departments and by university researchers under grants from state and national agencies. As a general rule, investigations done within the context of research unrelated to a current or imminent threat are not immediately essential to an action plan. This is the case when an investigation comes after an outbreak and does not turn up new cases of the disease. The results of research investigations may be summarized only to the sponsoring institution, and the investigators are at leisure to produce a paper that is then submitted to an appropriate journal for publication. If errors have been made, they damage only the reputations of the authors. However, when done within the context of an emergency or a continuing threat, field investigations are critical to control and stamping-out operations. If errors are made in this context, they can be serious.

In 1995, Wisconsin had its first case of bovine tuberculosis in 11 years. It was a single case, at first reported to have occurred in Oconto County but later discovered to have occurred in Shawano County, in a heifer thought to have been traded in from Michigan. This one case, which immediately cast a cloud over the state's $4 billion-a-year livestock industry, turned up alarming lapses in record-keeping by livestock dealers. Even more discouraging, when the events of 1995 (including a temporary suspension of Wisconsin's disease-free status) were subjected to intense scrutiny as ordered by the governor, the Wisconsin Department of Agriculture, Trade, and Consumer Protection was charged with "complacency, lack of professionalism, and substandard performance in animal disease investigation." What had happened was that the sick heifer, the single case, was discovered in April but not quarantined until July. Fortunately, the disease did not spread to other herds.

On October 11, 2000, USDA Secretary Dan Glickman declared a bovine tuberculosis emergency. Essentially an announcement of an expansion of the US tuberculosis eradication program, among other things it called for more testing:

"A decline in testing for tuberculosis in recent years also threatens to allow the spread of the disease in the United States. As the number of tuberculosis-free States has increased, limitations on Federal resources have in many cases led Department inspectors to take samples only from those animals exhibiting obvious signs of tuberculosis. The number of samples taken from cattle at slaughter for testing for tuberculosis has decreased from approximately 4,000 in 1995 to 900 in 1999. However, APHIS estimates that 10,000 sample submissions are needed each year to adequately survey the US cattle population for tuberculosis. APHIS needs additional funds, both to provide assistance in taking the number of samples at slaughter necessary for adequate surveillance and to increase testing capacity at the Department's National Veterinary Services Laboratories."[8]

With respect to bovine tuberculosis, this action is an important move away from the *ad hoc* intervention mode and perhaps signals a new era in which routine random sampling for diseases will inform US efforts in prevention and control.

D. Diagnostics and research: Over the past two decades, we have witnessed an explosion in biotechnology and the concomitant creation of diagnostic tools that not only distinguish between different strains of disease pathogens, but also between subtypes of those strains. We have tests that inform us if antibodies to certain disease pathogens have been formed by reaction to an infection or by vaccination. Moreover, some of these tools are being miniaturized into hand-held laboratories and packaged as kits for field use. Many lateral-flow tests yield results in minutes.

This bounty is counter-balanced by the realizations that it is now theoretically possible to create dangerous novel pathogens, and that the next generation of diagnostics must be capable of detecting the faint traces of genetic engineering—magnification or diminution of virulence; insertion of highly pathogenic virus into, or encapsulation within, a less infective or benign bacterium; and alteration of pathogenic sensitivity, such as increasing the tolerance of a virus to heat or light. These accomplishments, if we may use that word loosely, may lie down the road a bit, but they are all but certain, simply because there is no turning back, and because there exists no universal ethical imperative against them.

Research is crucial to meeting the threat of novel pathogens. But it must be research that explores possibilities—not just the standard buzzword threats, not just the Federation of American Scientists (FAS) Office International des Epizooties' (OIEs ) A and B Lists, and not just pathogens still in their birthday suits. To this end, flexibility should be built into the agenda for the proposed BL-4 laboratory at Plum Island. Perhaps one gets that by opening up all activities to Congressional oversight and by total and continuous commitment to safety and containment.

How can monitoring and surveillance assist in distinguishing between a natural outbreak and an intentional release of a disease agent? By informing the process by which the origin of an epidemic is discovered. The process is a combination of two major investigations conducted in tandem.

A. Diagnostics = Forensics

1. Sample (blood, tissue, skin scrapings, nodes, etc).
2. Identify causative agent, sequence for strain and subtype.
3. Compare the causative agent with
   (a) Strains and subtypes of agents prevously diagnosed in the US.
   (b) Strains and subtypes of agents found in Mexico and Canada.
   (c) Strains and subtypes found in countries of trading partners.
   (d) Strains and subtypes found around the world.

This part of the process is informed by disease surveillance on a global scale. At the present time, it is nonexistent in some countries, inadequate in many others, and incomplete even in the US. It is also informed by the pathogen banks at various diagnostic reference centers and collaborating centers associated with the OIE and the World Health Organization (WHO).

B. Epidemiology = Detective work

1. Inspect site and adjoining farms/facilities.
2. Sample animals on other farms/facilities.
3. Determine origin of animals (in-herd offspring, purchase, trade, stray?).
4. Determine recent history and movements of the animals.
5. Examine food, pasture, and water.
6. Interview farmers/owners and inspect records.
7. Investigate movements in and out of facility (visitors, employees, family members, vehicular traffic, light aircraft).
8. Review weather and wind patterns.
9. Analyze all of the above to establish or rule out a common pattern.
10. Identify index case or index situation.
11. Construct and test alternative hypotheses on origin of outbreak
12. Conduct further investigations as necessary.
13. Arrive at conclusions backed up by sound evidence.

This part of the process is informed by surveillance and record keeping on the local, state, and national levels, and supplemented as necessary by national intelligence.

One danger is that if the results from diagnostic tests show the causative agent to be identical to one associated with another country or region, there will be a temptation to focus the investigation on a suspect foreign origin and shortcut the process. Investigation is time consuming, but if followed methodically it will produce scientifically sound conclusions and prevent premature reactions that could embarrass the US government and the US scientific community.

Another danger is that because economic and political needs to control the outbreak are of such immediate consequence, resources may be devoted entirely to the stamping out, with detective work left until later. If this should happen, the investigation could easily be compromised and skewed.

To counter both of these possibilities, the US needs to have investigative teams similar to those used by the National Transportation Safety Board (NTSB)—teams composed of persons who can be objective and have no ongoing relationship with the USDA or state agriculture agencies, who are immediately available for dispatch to the outbreak location, and who have the same jurisdictional authority as the NTSB *vis à vis* the Federal Bureau of Investigation (FBI), National Guard, local or state police, etc.

Let us now consider a hypothetical outbreak:

On a family farm in southeast Texas, 20 miles from the Gulf Coast, a cow gets sick. Within several days, three more cows become ill. All of them are drooling. At that point, the farmer calls a neighbor to come take a look. The neighbor shakes his head and tells his friend to call Doc Jenkins, who is not a veterinarian but has long been the community's substitute and, as well, a major repository of home remedies. Later that day, Doc Jenkins stops by. Taking note of blisters in the cows' mouths and in their hooves, he says it looks like vesicular stomatitis. "Nothing to be done. No cure. I'll have to call the district offices and report this. Regulations, you know. They'll send somebody down to take a look. But I'd lay off slaughter. It's a serious disease, but some of them may be better in a week or so." Jenkins calls the district vet office before leaving to visit another farm in the area.

The next day, the district vet shows up, takes scrapings from the blisters, and says he'll get back to the farmer in a day or so. "In the meantime I don't want anyone or anything coming or going from here." The next day, the neighbor calls to say his cows are sick, too. The district vet calls to say that the first test was negative, and more tests will be done. Ten days have now passed since the first cow got sick. The farmer's entire herd is sick, with most down and not getting up, their hooves raw and disfigured. On the 11th day, he learns that other farms in the area have the same problem, but none other than his own has been inspected. "No need for all of us to call. Once we know what you have, we'll know what we have," say his neighbors.

On the 12th day, listening to the morning farm report, he hears that a large livestock producer to the north has been hit hard by an outbreak and that officials fear it may be foot and mouth disease (FMD). If so, it is the first time in the US since 1929. No animals are to be moved off farms until further notice. Roadblocks are up. Two days later, a state disease-control team arrives with the bad news for our farmer. It is FMD. All cattle and swine are to be destroyed. The farmer will be compensated for the loss. By sundown there is a graveyard back of the barn. The acrid smell of disinfectant hangs in the air.

The evening news is that a six-county area is under quarantine after a lab in Iowa confirmed FMD. Tens of large ranches and scores of small farms are involved. The state's agriculture department is dropping leaflets by helicopter, so farmers all over the state will know what to look for. The Congressman from the district is on television, saying it's believed to be the work of bio-terrorists from the other side of the world. But politics is always local, and the neighbor is on the phone saying, "I'll get you for this. You ignorant wetback!"

The next morning another team arrives at the farm and starts asking questions. After covering what we already know of the tale, the farmer is asked, "When was the last time you got any new stock?" He replies, "Over a year ago. That is, except for some pigs about six months ago, and two goats we got a few weeks back, but didn't keep." To more questions come more answers: they were a gift; his cousin found them near the causeway to the beach at Galveston. "Knew they didn't belong to anybody around there. Fancy houses. No farms. My cousin had no place to keep them. Gave them to me. Birthday present, he said. I don't like goats that much. And these two walked funny. We slaughtered them when we got home. Meat's in the freezer."

Later that week, the farmer gets a call. " Lucky for us you froze the meat. We found the virus. As soon as you told us about the goats walking funny, we thought it was them. Sore feet on a goat can be a sign. Too bad you didn't know what to look for."

What to look for. . .

A recent study entitled "Potential Impact of Foot-and-Mouth Disease in California," done by Javier Eckboir while he was a post-doctorate fellow at the University of California at Davis, is an overview of the disease and a detailed analysis of a hypothetical outbreak in Tulare County, California. In a published comment to the study, Hans Riemann, Professor Emeritus at the UC School of Veterinary Medicine, writes:

> "The creation of huge data bases and large committees for early detection or tracing of FMD is only one approach, and not necessarily the most important. Farmers and their employees are the ones who must be relied upon for reporting of infected herds. Tracing exposed herds depends on local conditions, and the detective acumen of the responsible veterinarian(s). Misdiagnosis is likely, and farmers should be encouraged to report not only suspect lesions. The first thing that happens when an animal gets FMD is that it stops eating and producing milk. This is something the dairy operator will invariably observe, and should be encouraged to report if two or more animals are affected.
>
> "During the Pennsylvania avian influenza epidemic in 1983, it was observed retrospectively that the affected flocks showed a significant drop in feed and water consumption two weeks before peak mortality. Early warning systems based on abnormal changes in consumption or production parameters may be applicable to other diseases such as Newcastle disease and FMD. There will be false alarms, but even these will provide opportunity to educate farmers and improve their operations."

What to look for. . .

Since 1996, the Federation of American Scientists (FAS) AHEAD/ILIAD project for promoting global animal disease surveillance has been involved in forming an operational program in a sub-Saharan Africa country that will focus on the interface between wild animals and livestock in remote farming communities. The foundation of this bottom-up approach to disease surveillance is training others in what to look for and providing the tools necessary to do the looking.

Over the past three years there have been repeated reminders by provincial and district veterinary officers that the small farmers and pastoralists of Africa know their animals to the point that they can recite the full family tree and personal history of each head of cattle, and that what they don't know is how to recognize the earliest signs of certain diseases and how to get help when they need it, as opposed to getting help when they don't. As one reviews disease outbreaks in the United States and the threat of more to come—from whatever source and in whatever way – the thought occurs that the need for disease recognition training for farmers and the employees of large production enterprises may be as great here as it is in Tanzania. Given the differences in the respective livestock systems and the frequency of serious disease outbreaks in Africa, the need for education here, especially on diseases rarely seen in the US, may perhaps be even greater.

More and more it has become evident that it will be wise to expand the parameters of the investigative element of surveillance—disease forensics and detective work—to include the "eyewitness"—the first person always at the scene of the crime—the people who day by day have the most contact with the potential targets of agro-terrorism and economic sabotage. Teaching these farmers and facility employees, and rewarding in some way their participation as sentinels, might well make the difference in addressing the threat of agro-terrorism and economic sabotage.

Finally, to briefly revisit the FMD outbreak scenario, let us suppose that the epidemiological investigation turned up the following:

1. An eyewitness account of a sailor in a dinghy unloading two goats at a point on the Galveston beach on the same day the goats were found by the farmer's cousins.

2. Confirmation that the sailor who released the animals (a) had joined the freighter crew at Buenos Aires, (b) had brought the goats on board as a gift to the freighter cook, who intended to slaughter them for an on-board barbeque while in Galveston Bay, (c) was the grandson of an Argentine rancher who had been bankrupted when the US reimposed a ban on the import of meat from that country, and (d) was a member of an anti-US movement in the Argentine capital.

3. Statement from the freighter captain that the sailor had sent an unauthorized radiogram to his mother hours before the goats were taken from the freighter with the message "Goats arrived Galveston safely. Off-loading today."

4. Explanation from the sailor that he had grown fond of the animals and released them because he could not bear to see them slaughtered, that the radio message was to let his mother know that he had resolved his dilemma about the goats, a dilemma he had mentioned in a earlier letter to her, and that he had no idea the animals were sick.

5. No recovery of FMD virus from the freighter storeroom where the animals had been kept for fattening up during passage.

After mulling over the results of the investigation, and still suspicious of a personal vendetta, Texas state agriculture officials consulted with the FBI, which in turn consulted with the US Departments of State and Defense. The bottom line, in the words of an unidentified Pentagon official: "What can we do? We already have a ban on Argentine meat. The sailor says he's sorry. Even if he's not and he intentionally introduced the virus to get back at us, it doesn't come under the espionage act,[9] and putting two sick goats ashore isn't covered by the biological weapons treaty. If he was from Cuba or Libya or Afghanistan, we would probably try to make a case. But we're talking about Argentina. Argentina had nothing to do with this. Argentina's one of our hemispheric partners. Argentina's a friend. They have promised to keep a close watch on the sailor and on the organization that's been identified."

One could say that this gives new meaning to the saying, "barring the barn door after the horse has bolted," but in real and practical terms the prospects for countering agro-terrorism and economic sabotage depend to a large extent on the ability of the US to erect a workable, fair, and effective gate to its own barn. Such a gate will close softly most of the time, but slam shut when necessary. Yet, however it is configured and operated, it will not be able to keep every threat outside. For example, once the hypothetical FMD scenario was in motion, preventing it from playing out, to the tune of a $10 billion loss in trade and a $10 million cost to stamp out the epidemic, would have been nigh impossible. One could suggest new and highly restrictive regulations—including one requiring inspection of all transport entering the US, one requiring confiscation and destruction of all animals and fresh and processed meats found aboard such transport, and one requiring quarantine of all personnel and a ban against entry to such transport by others pending results from diagnostic testing. It is not clear, however, that such measures applied to the scenario would have guaranteed success. After all, the sailor could have launched the goats in the dinghy on the in-going tide before US inspectors boarded, and hoped for the best, or worst as it may be. Moreover, had the highly restrictive regulations been in effect, it is not likely that the investigators would have gotten any information from the crew and captain.

Once a threat slips through the gate, it will be up to the agriculture community—primarily the farmers and ranchers, veterinarians, county and state agencies—to catch it quickly. And the single, most essential factor in catching the threat will be recognizing it when it turns up in some out-of-the way place. What to look for!

## References

1. Dorothy B. Preslar is Director of AHEAD/ILIAD. AHEAD and ILIAD are acronyms, respectively, for Animal Health/Emerging Animal Diseases, a policy project; and International Lookout for Infectious Animal Disease, an operational program for developing countries, at the Federation of American Scientists.
2. Pathogens include bacteria, viruses, rickettsia, protozoa, fungi, and expressed toxins.
3. "First," if the *thrips palmi* charge by Cuba against US-based operations was false.
4. A pathogen or pest not known to be present in the US at the time of infection.
5. A pathogen, toxin, or pest modified or engineered through any biotechnological process or biochemical construction.
6. A pathogen or pest existing in a country or area on a continuous basis, usually but not necessarily resulting in sporadic infection or infestation.
7. A pathogen or pest that was in the past (at least a decade ago) eradicated from a country or area.
8. 65 FR 63227.
9. Economic Espionage Act of 1996, 18 United States Code 90.

# Conclusions

## Framing the Issue

This workshop has illustrated that the threat of agricultural bioterrorism is more complex than high-vulnerability, high-consequence scenarios suggest. As with bioterrorism in general, analyses of agricultural bioterrorism have been based on worst-case scenarios and have too often been vulnerability driven, rather than based on empirical evidence of terrorists' intentions or a credible analysis of the technical hurdles to achieving widespread damage. Part of the problem, however, stems from a lack of empirical data. There are almost no historical examples of terrorists attempting to use biological weapons to attack agriculture, and the few known cases are closer to tactical or disruptive assaults than to devastating strategic attacks on a country's agriculture or economy. The objectives of terrorists in attacking agriculture, and the nature of such an attack, thus remain obscure.

## Terrorist Motivations

An understanding of terrorist groups' motivations is an important aspect of a meaningful threat assessment. This remains lacking from open sources. Therefore, we are left with educated speculations on possible motivations for agricultural bioterrorism. Such motivations may encompass both political and economic objectives. The attacker may seek to damage the US agricultural sector in order to call attention to some political or ideological concern, or the attack may be designed to foment panic or to undermine public confidence in the US government. More insidiously, the attack may be aimed at consumers themselves. A state-sponsored attack may have similar goals, or it may involve a bid to increase the sponsoring country's share of the world agricultural market. Clearly, the motivations for an agricultural bioterrorist attack could be quite varied.

Given these considerations, agricultural bioterrorism could be chosen as a means to avoid the risk of incurring massive retaliation that might follow the use of nonconventional weapons against humans. The potential for economic and political destabilization would make such an attack appealing to a broad range of groups, such as politically motivated, single-issue groups, as well as some criminal organizations seeking financial gain. However, the probable consequences of sabotage or a more widespread attack need to be considered. Would agricultural bioterrorism offer a significant advantage over other forms of attack in accomplishing terrorist objectives? Mixed opinions were expressed at the workshop.

Also during the workshop, the relationship was explored between state use of biological weapons against agriculture and agricultural bioterrorism. Historically, the sole developers of large-scale or potentially effective anti-crop or anti-livestock weapons have been states, not terrorist groups. At the very least, state programs offered points of comparison for identifying some of the pathogens and methods that substate groups might employ. As a caveat, however, the validity of any direct comparison is questioned, as the motivations for states and terrorists are clearly not synonymous. States generally want to cripple an enemy, either by eliminating its military capacity, attacking its population, or otherwise destroying its ability to fight and achieve its goals. Perhaps terrorist groups, such as nationalist separatist groups determined to change their geopolitical situation, resemble aggressive states. Therefore, these groups may be more likely than other groups to perpetrate agricultural bioterrorism because it allows them to strike directly at the enemy. Groups with similar, although less profound, agendas could see agricultural bioterrorism as a useful way to harass or disrupt the economy of their enemy. In doing so, it may not be necessary for such groups to do more than make a credible threat or hoax.

To date, the majority of terrorist attacks on agriculture have been closer to consumer-product tampering than the high-impact attacks that appear to be the present focus of concern within the United States. In addition, most recorded "attacks" have in actuality been ambiguous or fraudulent allegations of a bioweapons attack. In spite of this, the impact of an attack on agriculture may be out of proportion to its degree of success. Even a largely unsuccessful attack has the potential to undermine consumer confidence in that product or industry. It is precisely this ripple effect that makes it difficult to gauge the impact of an agricultural bioterrorism event.

## Costs

The workshop has revealed that agricultural bioterrorist attacks could have both short-term and long-term impacts, with a wide range of associated costs. Destruction of crops or livestock would have a direct financial impact on the grower, breeder, and consumer. Clearly, if a particular crop is in short supply, or if it has to be imported from a more remote region, then the price of that good will rise. In a broader sense, the effect may spread if various industries depend on certain crops or livestock. For example, if the cattle industry experiences a bioterrorist attack, it would affect not only the farmer but also the livestock shippers, stockyards, slaughterhouses, distributors, and so on. When assessing the costs of agricultural bioterrorism, it is therefore important to consider the impact of an attack on the entire production cycle.

Moreover, as the foot-and-mouth disease (FMD) disaster in the UK shows, because of the quarantine restrictions on the sale or movement of animals, a serious outbreak of a highly contagious disease has a profound economic impact not only on those farmers with infected animals, but also on those without. Apart from immediate revenue losses, long-term effects may result from the loss of market share and other factors. If distributors, wholesalers, and retailers find acceptable and affordable alternative sources of agricultural products, it is possible that they may not return to their original supplier even after the crisis has passed. In other scenarios, there could be the need to replace entire crops or livestock. The resulting expense could be heavy if, for example, breeding stocks have to be replaced. Depending on the pathogen used in the attack, there is also the likely need to decontaminate the affected area. These costs may include not only the expense of "cleaning up" the agent, but also the destruction of infected crops or livestock. Finally, industries not even connected to agriculture may be affected. Although estimates vary, the FMD outbreak cost the UK tourism industry several billion pounds sterling because of decreased travel from foreign and domestic tourists.

Trying to assess the costs associated with an agricultural bioterrorist attack is problematic, again because of the lack of data about such attacks. Under these circumstances, worst-case scenario analysis predominates at the expense of more objective and realistic conclusions. One important point that emerged from the workshop was that the vulnerabilities of crops and livestock are distinct from one another. For example, rice or wheat crops might be sufficiently widely distributed to make it hard for an agricultural bioterrorist attack to have much of an impact. In contrast, beef cattle are processed in a concentrated manner and may therefore be more vulnerable, particularly to a highly infectious and contagious agent such as FMD. Even in a widely distributed segment of the agricultural economy, there may be key nodes that could be attacked. Costs in this area are necessarily speculative, but would be based on an assessment of the value of either the agricultural sector as a whole or more likely some part of it, combined with analysis of the extent to which an agricultural bioterrorist attack had damaged that portion of the sector.

Any assessment of the impact of agriculture terrorism must weigh the costs of the possible attack, the costs of preparation for the attack, and the likelihood of the attack, balancing the costs of preemption and response. Preparation costs may be the most quantifiable in that it is possible to estimate how much it would cost to reform certain elements of the agricultural economy, such as livestock production. For example, it is possible to envision a model that estimates the specific costs associated with making beef production less concentrated and therefore less vulnerable to attack. Such changes, however, may bring significant expense to the industries involved. Without a credible, impending threat, the agricultural industry may deem significant changes to current livestock practices as cost-prohibitive. At the present time, the US agricultural sector is sufficiently diverse and vast to preclude a crippling bioterrorist attack on US agriculture and its economy as a whole. Nevertheless, these proceedings show that certain local, state, or regional portions of the US agricultural economy could suffer significant harm from serious disease outbreaks.

## Feasibility

Assessing the likelihood of an agricultural bioterrorist attack is difficult. Although it is easy to speculate about the capabilities and materials theoretically available to terrorists, it is impossible to predict terrorist incidents with any precision. This is particularly true for agricultural bioterrorism because of the lack of empirical data on the phenomenon. In this vacuum, assessments rapidly spin to worst-case analysis unless one attempts to tie the assessment to real-world situations. A critical component of such assessments is the feasibility of significant agricultural bioterrorist attacks.

In this discussion, it is important to differentiate the technical issues involved in using animal and plant pathogens against agricultural targets. The use of certain animal pathogens for local or widespread agroterrorism appears to be technically easier than using plant pathogens. Certain animal pathogens are relatively easy to weaponize because they have (1) high infectivity (because of ease of either biological or mechanical transmission), and (2) environmental hardiness. Furthermore, because the United States has quarantined its livestock against foreign animal diseases and has supported the practice of livestock concentration, US livestock may be more vulnerable to rapid and devastating disease outbreaks, whether intentional or natural. In contrast, bioterrorism involving plant pathogens is unlikely to cause widespread destruction because of the inability of a perpetrator to control weather conditions over large regions and long periods of time.

The ensuing debate regarding terrorist capabilities suggests that it would be possible for terrorists with some minimal level of expertise to acquire and deliver pathogens for sabotage purposes. Pathogens are available from a host of international laboratories, and technical information on these pathogens is available on the Internet and from the local university library. The process of turning these pathogens into weapons, however, is fraught with certain complicating factors that may require a certain level of scientific expertise and ability. Except in the case of a few foreign animal diseases, this seems to suggest that the technical threshold for launching a significant agricultural bioterrorist attack may still be relatively high, at least as high as a conventional attack. Nevertheless, terrorists seeking to cause mass disruption could do so by carrying out a lower-level attack (or hoax) that is highly publicized. With this in mind, there remains a need for a more detailed assessment of the technical barriers to effective acquisition and use of an anti-agriculture weapon.

In light of the limited historical record on terrorism or warfare directed at agricultural targets, one can ask, is the paucity of incidents the result of technical constraints involved in launching effective agricultural bioterrorist attacks or simply a lack of motivation on the part of the potential perpetrators? As has been mentioned previously, substate and state attacks on agricultural targets have been small-scale, localized incidents. In substate attacks, the majority of incidents have involved consumer-product tampering rather than widespread releases. Even in state-level programs, the purpose of the attacks has tended to be sabotage, rather than to cause widespread destruction of livestock or a nation's food supply. These findings seem to suggest that localized attacks are technically more feasible than widespread attacks because of the difficulty in controlling infection and environmental conditions over large distances. Moreover, effective response strategies such as quarantine, application of fungicides, disinfectants, and vaccination can lessen the more devastating and widespread effects of animal or plant diseases. These observations appear to support the argument that all pathogens (whether against humans, plants, or animals) have strengths and weaknesses that must be considered for states or terrorists seeking to develop them into effective biological weapons.

## Key Response Issues and Recommendations

Because the jury is still out on whether agricultural bioterrorism is a "clear and present danger," policy responses should be pursued that would be beneficial in the event of both natural and malicious disease outbreaks. In dealing specifically with the issue of agro-terrorism, the United States should develop a range of responses. The following list of policy recommendations is based on the foregoing summary of the perspectives and analysis presented at the workshop and represents some ways that the US government can better understand and address this enigmatic issue.

In general, the United States needs to strengthen the norm against using biological weapons—whether directed against humans or agriculture. Washington must also increase the cost of doing so, whether by making an effective attack more difficult to achieve or by seeking to deter individuals, groups, and countries from launching such an attack for fear of the consequences. To do this, however, requires a greater understanding of terrorist and state motivations, as well as insider threats within the agricultural sector. More case studies should be undertaken to explore these issues.

Disease surveillance is clearly of paramount importance in addressing the threat of agro-terrorism. Livestock and crops are monitored regularly for signs of disease, and farmers are required to report key diseases to central authorities to help to mitigate the effects of an outbreak. In addition, a national centralized database of information on foreign animal diseases, such as FMD, from various international sources (e.g., Russia, China) would increase surveillance capabilities. If suspicion arises that a disease outbreak may have been deliberately induced, it will be necessary to go beyond the standard epidemiological investigation and collect forensic evidence for further action by law enforcement or the national security community.

Furthermore, communication among scientists concerned with animal, human, and plant diseases should be increased. Currently, there are only limited interactions between the public health and veterinary sectors. This problem became apparent during the 1999 West Nile virus outbreak, when the existing surveillance and response structures among public health, veterinary, and other scientific communities were unable at first to draw the connection between outbreaks in birds at the Bronx Zoo and human cases. In addition, some plant diseases have been found to cause disease in people with compromised immune systems. Because many emerging diseases originate in the wild, better contact and communication among all scientific communities (and pooling of resources, such as diagnostic capabilities) could assist in earlier identification of disease outbreaks. Increased funding for research related to nonnative animal and plant diseases also offers enormous benefits for US public health and agriculture.

Beyond surveillance, the FMD outbreak in the UK serves as a reminder of the need for rapid and integrated response capabilities, including other means of detection and responder training. One of the key benefits of the US Domestic Preparedness Program, which trains responders to potential terrorist incidents involving weapons of mass destruction, has been the emphasis on cross-jurisdictional cooperation. In the area of response to agro-terrorism, there is a similar need for programs enabling groups that are unfamiliar with one another and their respective methods and requirements to train together and coordinate their activities. Such efforts would increase the likelihood that the full range of capabilities would be brought to bear.

Increased public education efforts could also go a long way in mitigating a disease outbreak. Most local veterinarians and farmers would be the “first-responders” to an agricultural disease outbreak. However, these individuals probably have little experience in identifying FMD. Therefore, there is a need to increase education, from the grassroots to the university level, on foreign animal and plant diseases and how these “first responders” can contact appropriate officials to report a suspected outbreak. There is also a need for policies to determine the larger public’s role in the event of an outbreak and how best to manage information.

The phenomenon of agricultural bioterrorism raises some broader issues that should also be considered. Should agricultural bioterrorism be regarded as a public health, national security, economic, law enforcement, or purely agricultural issue? Even if the answer is probably a combination of these, the jurisdictional “who’s in charge?” problem remains. Should the primary agency or department responsible for managing an incident of agricultural bioterrorism be the US Department of Agriculture (USDA), the Federal Bureau of Investigation (FBI), or some other body? Obviously, the precise details of the incident are an important determinant of how this dilemma would be resolved in each case. As with putative bioterrorist incidents directed against humans, tensions exist among the health, containment, and investigative functions that would all be elements of a response to an act of deliberate contamination.

There are also issues of multiple, overlapping levels of government and concomitant responders. For example, what should be the relationship between veterinarian officials at the local, state, and federal levels when responding to a local outbreak of a major listed disease, such as FMD? This question relates not only to which level of authority has primacy, but also to the respective roles and the mechanism by which each agency would become involved in responding to an incident. Many of these relationships are relatively well established for responding to naturally occurring outbreaks of disease, but how would these relationships change if the scale of a disease outbreak increased or the outbreak was induced deliberately?

From the above discussion, it is clear only that much about agro-terrorism remains unclear, and that the historical record provides little help in resolving this lack of clarity. The motivations of putative terrorists seeking to attack US agriculture, along with their ability to do so, remain largely a matter of speculation. Obviously, low-level or sabotage attacks are well within the capability of even a technically unsophisticated group. A strategic attack, or even one that devastated the entire sector, appears less likely: as an analog, the FMD outbreak in the UK had only a finite, albeit widespread, impact. However, the vulnerability to attack varies among different parts of the agricultural sector and may result in long-term as well as immediate costs. Meaningful assessments of the problem must not only recognize this, but also provide solutions that take account of the variegated nature of the sector. Understanding and responding to the threat of agricultural terrorism require assessing terrorist capabilities and motivations, as well as estimating potential costs and developing strategies for addressing the threat. These proceedings have raised a number of key issues and suggested some recommendations for further work and policy development. This volume has sought to disaggregate the various elements of a realistic threat assessment of agricultural bioterrorism, including terrorist motivations, capabilities, and the vulnerability of the agricultural sector. With these different factors in mind, this discussion will hopefully provoke additional debates and aid in crafting sensible policies to reduce the likelihood and impact of agricultural disease outbreaks, whether natural or intentional.

# Appendix A: Workshop Program

**Agro-Terrorism: What Is the Threat?**
November 12-13, 2000
Statler Hotel & J. Willard Marriott Executive Education Center
Cornell University, Ithaca, NY

**Sunday, November 12, 2000**
(All events are in the Yale/Princeton Room of the Statler Hotel, unless otherwise noted.)

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| 8:00–8:30 a.m. | **Continental Breakfast** |
| 8:30–9:00 a.m. | **Welcome and Introduction**<br>**Judith Reppy**, Peace Studies Program, Cornell University<br>**Amy Sands**, Center for Nonproliferation Studies, Monterey Institute of International Studies |
| 9:00–10:00 a.m. | **Panel I: Outlining the Issues**<br>WMD Terrorism: Is Agriculture a Likely Target in the Changing Face of Terrorism?<br>**John Parachini**, Center for Nonproliferation Studies<br>Agricultural Terrorism: Assessing the Impact and Attack Against U.S. Agriculture<br>**Jason Pate**, Center for Nonproliferation Studies |
| 10:00–10:30 a.m. | **Coffee Break** |

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|---|---|
| 10:30–12:00 noon | **Panel I: Discussion**<br>Discussant/Moderator:<br>**Michael Moodie**, Chemical and Biological Arms Control Institute |
| 12:00–1:00 p.m. | **Lunch** (Taylor A&B Banquet Rooms) |
| 1:00–3:15 p.m. | **Panel II: Technical Issues**<br>Technical Feasibility of Anti-Crop Terrorism<br>**William Fry**, Department of Plant Science, Cornell University<br>Assignment: Think Like a Terrorist<br>**Donald Schlafer**, School of Veterinary Medicine, Cornell University<br>Moderators/Discussants:<br>**Martin Hugh-Jones**, School of Veterinary Medicine, Louisiana State University<br>**Anne Vidaver**, Department of Plant Pathology, University of Nebraska |
| 3:15–3:45 p.m. | **Coffee Break** |
| 3:45–5:00 p.m. | **Panel III: Case Studies**<br>State Agro-Biological Warfare Programs<br>**Simon Whitby**, Department of Peace Studies, University of Bradford, UK<br>The Political Terrorist Threats to U.S. Agriculture and Livestock<br>**Peter Chalk**, RAND Corporation<br>State-Level vs. Substate Programs Utilizing Anti-Plant and Anti-Animal BW Agents: Is There a Link?<br>**Milton Leitenberg**, Center for International and Security Studies, University of Maryland |
| 5:00-6:00 p.m. | **Panel III: Discussion**<br>Discussant/Moderator:<br>**Jonathan Tucker**, Center for Nonproliferation Studies |
| 6:30- 7:00 p.m. | **Cocktail Reception** (Johnson Art Museum, 6$^{th}$ Floor) |
| 7:00–9:00 p.m. | **Dinner** (Johnson Art Museum, 6$^{th}$ Floor)<br>Dinner Presentation:<br>**David Huxsoll**, U.S. Department of Agriculture, Plum Island Animal Disease Center |

**Monday, November 13, 2000** (All events are in the Taylor A&B/Rowe Rooms of the Statler Hotel, unless otherwise noted.)

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| 8:30–9:00 a.m. | **Continental Breakfast** |
| 9:00–10:00 a.m. | **Panel IV: Response and Countermeasures**<br>Plant Disease Invasion and Persistence: What Are the Epidemiological Consequences When a Plant Pathogen Is Introduced into a Susceptible Crop?<br>**Larry Madden**, Department of Plant Pathology, Ohio State University<br>Lessons from West Nile for BW Terrorism Response<br>**Tracey McNamara**, Wildlife Conservation Society, Bronx Zoo<br>The Importance of Disease Monitoring and Surveillance in the Watch for Agro-Terrorism or Economic Sabotage<br>**Dorothy Preslar**, Federation of American Scientists |
| 10:00–10:30 a.m. | **Coffee Break** |
| 10:30–11:30 a.m. | **Panel IV: Discussion**<br>Moderator/Discussant:<br>**Gavin Cameron**, Belfer Center for Science and International Affairs, Harvard University |
| 12:00–1:30 p.m. | **Lunch/Workshop Wrap-Up**<br>Agro-Terrorism Threat Assessment Summary<br>**Amy Sands**, Center for Nonproliferation Studies |

Workshop concludes at 1:30 p.m.

Co-sponsored by The Center for Global Security Research, The Center for Nonproliferation Studies, and The Peace Studies Program

# Appendix B: List of Workshop Participants

Jorge Andrade-Piedra, Department of Plant Breeding, Cornell University

Max Appel, College of Veterinary Medicine, Cornell University

Jonathan Ban, Chemical and Biological Arms Control Institute

Gavin Cameron, Belfer Center for Science and International Affairs, Harvard University

Rocco Casagrande, Harvard Medical School

Peter Chalk, RAND Corporation

John Cloud, Peace Studies Program, Cornell University

Eric Croddy, Center for Nonproliferation Studies, Monterey Institute of International Studies

William Fry, Department of Plant Pathology, Cornell University

Jessica J. Hellmann, Center for International Security and Cooperation, Stanford University

Martin Hugh-Jones, School of Veterinary Medicine, Louisiana State University

David Huxsoll, U.S. Department of Agriculture, Plum Island Animal Disease Center

Anne Kohnen, Belfer Center for Science and International Affairs, Harvard University

Milton Leitenberg, School of Public Affairs, University of Maryland

John Lightfoot, Federal Bureau of Investigation

Larry Madden, Department of Plant Pathology, Ohio State University

Hilary Mayton, Department of Plant Breeding, Cornell University

Tracey McNamara, Wildlife Conservation Society, Bronx Zoo

Piers D. Millett, Department of Peace Studies, University of Bradford, UK

Michael Moodie, Chemical and Biological Arms Control Institute

Randall Murch, Defense Threat Reduction Agency

John Parachini, Center for Nonproliferation Studies, Monterey Institute of International Studies

Jason Pate, Center for Nonproliferation Studies, Monterey Institute of International Studies

Dorothy Preslar, Federation of American Scientists

K.V. Raman, Department of Plant Breeding, Cornell University

Judith Reppy, Peace Studies Program, Cornell University

Reynolds Salerno, Cooperative Monitoring Center, Sandia National Laboratories

Amy Sands, Center for Nonproliferation Studies, Monterey Institute of International Studies

Donald Schlafer, School of Veterinary Medicine, Cornell University

Paul Shadbolt, Canadian Food Inspection Agency

Barry Strauss, Peace Studies Program, Cornell University

Jonathan Tucker, Center for Nonproliferation Studies, Monterey Institute of International Studies

Anne K. Vidaver, Department of Plant Pathology, University of Nebraska

Kathleen Vogel, Peace Studies Program, Cornell University

Andrew Weber, Department of Defense

Berthold Weinstein, Lawrence Livermore National Laboratory

Simon Whitby, Department of Peace Studies, University of Bradford, UK

# Appendix C: Contributers

**Gavin Cameron**

Gavin Cameron is a lecturer in the Department of Politics and Contemporary History at the University of Salford, England. He was formerly a Fellow in the Executive Session on Domestic Preparedness at the Belfer Center for Science and International Affairs at Harvard University. He has also served as a Senior Research Fellow (1999-2000) and Postdoctoral Fellow (1998-1999) at the Center for Nonproliferation Studies, part of the Monterey Institute for International Studies in California. He received a Ph.D. in international relations from the University of St. Andrews, Scotland, and is author of *Nuclear Terrorism: A Threat Assessment for the 21st Century* (St. Martins Press/Macmillan, 1999). His research focuses on terrorism, particularly on the threat of WMD terrorism, and on possible responses to that threat.

**Peter Chalk**

Peter Chalk is a policy analyst working in the Project Airforce and National Security divisions of the RAND Corporation, Washington DC. Recently, he was a major contributor to the First Annual Report of the Gillmore Commission, a Congressionally mandated advisory panel established to assess US domestic response capabilities for terrorism involving weapons of mass destruction. Prior to joining RAND, Dr. Chalk was an Assistant Professor of Politics at the University of Queensland, Brisbane, and a Postdoctoral Fellow in the Strategic and Defense Studies Centre of the Australian National University, Canberra. He is author of the forthcoming book *Non-Military Security and Global Disorder: The Impact of Extremism, Violence and Chaos on National and International Security* (Macmillan, 2000) and *West European Terrorism and Counter-Terrorism: The Evolving Dynamic* (Macmillan, 1996). Dr. Chalk currently represents the US on the Council for Security Cooperation in the Asia Pacific's (CSCAP) Working Group on Transnational Organized Crime. He is also Associate Editor of *Studies in Conflict and Terrorism*.

**William Fry**

Bill Fry received his Ph.D. in Plant Pathology at Cornell University in 1970. His first academic position was teaching biology at Central Connecticut State College in New Britain, CT (1970-1971). Subsequently, he moved to the Plant Pathology Department at Cornell. He has had two sabbatical leaves: one at the University of California (Davis) in 1978-1979, and one at the Wageningen Agricultural University in the Netherlands (1989-1990). He has served as chairman of his department (1981–1995), president of his national professional society (American Phytopathological Society) in 1995/1996, and faculty Trustee of Cornell University (1998-2002). His research has had two thrusts: (1) Epidemiology and management of plant disease with special emphasis on Late blight of potato (caused by *Phytophthora infestans*) employing field experiments, simulation modeling, and laboratory and greenhouse experiments; and (2) Biology (genetics, developmental, pathogenicity) of *Phytophthora infestans*, with emphases on migration effects on population structure and the attendant implications to disease management, genetic control of specific biological traits, and discovery of genes involved in different developmental stages.

**Milton Leitenberg**

After a half dozen years as an academic and researcher in the sciences, Milton Leitenberg began work in the field of arms control in the fall of 1966. In January 1968, he went to Sweden as the first American recruited to work at the Stockholm International Peace Research Institute (SIPRI). He later worked at the Swedish Institute of International Affairs and at the Peace Studies Program, Cornell University. Since 1989, he has been a fellow and visiting scholar at the Center for International and Security Studies at the University of Maryland. In the years since 1966, Leitenberg has authored or edited a half-dozen books and written more than 135 papers, monographs, and book chapters. As regards biological weapons (BW), his first papers dealing with the subject were published in 1967, and he was part of the team at SIPRI that produced the six-volume set on "The Problem of Chemical and Biological Warfare." Since 1992, he has written or published some 20 papers dealing with various aspects of BW: the program of the former USSR, BW proliferation, and the current response in the United States to the issue.

**John Parachini**

Mr. Parachini is the Director of the Washington, DC, office, Center for Nonproliferation Studies, Monterey Institute of International Studies. He recently authored motivational case studies on the Weather Underground and the 1993 World Trade Center bombing published by MIT press in a volume entitled *Toxic Terror: Assessing Terrorist Use of Chemical and Biological Weapons*, edited by Jonathan B. Tucker. Prior to assuming his current position, Mr. Parachini was a Senior Associate at the Henry L. Stimson Center. Mr. Parachini has taught at the University of Southern California and Baruch College of the City University of New York. He has had several short assignments at the US State Department in the Operations Center, the Bureau of Political-Military Affairs, Intelligence and Research, and Oceans, International Environments and Scientific Affairs. Mr. Parachini holds an MBA from Georgetown University and an MA in International Relations from Johns Hopkins University's School of Advanced International Studies.

**Jason Pate**

Jason Pate is a Senior Research Associate and Manager of the Chemical, Biological, Radiological, and Nuclear (CBRN) Terrorism Database for the Chemical and Biological

Weapons Nonproliferation Project (CBWNP), focusing on terrorism involving weapons of mass destruction. He is co-author (with Dr. Jonathan B. Tucker) of a case study in which a militia group acquired a biological toxin, forthcoming as a chapter in a compilation of such incidents. His research interests also include: terrorist incident prevention, response, and management; theater and national missile defense; European security and the future of NATO; and U.S. military policy. Before joining the Center for Nonproliferation Studies (CNS), Monterey Institute of International Studies team in February 1997, Pate was a Research Assistant for the Scientific and Technical Committee at the North Atlantic Assembly, the interparliamentary body for NATO, in Brussels, Belgium. His work there focused on military technology proliferation, chemical and biological weapons proliferation, nonlethal weapon technologies, and the future of the Atlantic Alliance.

**Dorothy Preslar**

Dorothy Preslar works with the Federation of American Scientists (FAS) in Washington. She founded the Animal Health/Emerging Animal Disease (AHEAD) policy project in 1995 and the International Lookout for Infectious Animal Disease (ILIAD), the operational surveillance endeavor, in 1998. From 1994 to 1999, she also served as the Washington staff officer for the FAS Biological Weapons Convention (BWC) Verification and ProMED initiatives. Since 1998, she has been conducting joint research with the Stockholm International Peace Research Institute on technology transfers in a BW proliferation environment, currently co-authoring a book to be published next year. Dorothy is a graduate of Wake Forest University and the author of several papers dealing with emerging disease threats to the increasingly globalized structure of international security.

**Simon Whitby**

Simon Whitby is a Research Fellow at the Department of Peace Studies, University of Bradford, UK. He earned his Ph.D. on "Anti-Crop Biological Warfare and its Control" from the University of Bradford, UK, in July 2000. He is now in the process of editing a single-authored book manuscript for publication by Macmillan in 2001. He also co-authored an article with Paul Rogers and Malcolm Dando in *Scientific American* (June 2000) entitled, "Germ Warfare Against Crops." His research has also involved the Biological and Toxin Weapons Convention (BTWC). Most recently he has filmed and edited a series of nine web videos relating to key aspects of the negotiations to strengthen the BTWC. He has recently given a lecture to the Chemical and Biological Warfare Colloquium, Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, Boston.

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